UNIVERSITY OF TASMANIA

Department of Electrical and Electronic Engineering

MTECH Thesis Project

PLC Controlled Cascaded Water Tank System

By:

Cesar S. Mendoza

Supervisor: Dr. David Lewis

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ABSTRACT

This project demonstrates the extensive application of the Siemens S5-95U Programmable Logic Controller. It utilises almost all the features of a good programmable controller now available in the market.

The PLC's most notable feature, the handling of analog input and output data is actually the main feature of this project. The water tank system is composed of 3 tank systems connected in cascade series. Tank 1 is used for cold water storage, and tank 2 is the one used in the process. An interface module was created that displays the system different parameters. These are the tank's temperature and level. The interface is a stand-alone module which only requires power and the systems inputs. The module displays the system's current reading through an LED bar graph.

The system setpoints can all be adjusted on the module. The controller generates a digital control bit depending on the desired system operation. This programmable controller and interface module work in conjunction with the existing water tank system found in the control laboratory.

PROJECT OVERVIEW

The cascaded water tank system project was introduced in conjunction and as an extension of the original idea of controlling the level and temperature of water in two tanks using the Festo PLC. From that original idea, the water tank system is controlled by one PLC each. The control scheme was digital since the analog signal that came from the system was converted first to digital signal via electronic circuit, which is then processed by the Festo PLC that only accepts digital inputs.

In this project, the Siemens S5-95U PLC which can handle analog signals was used. A signal conditioning and interface module (SCIM) that will handle the raw analog signal from the system was designed. The output of the SCIM was then connected to the PLC so that it could process the data and produce the necessary control signal that is then fed to the different output devices of the system.

One main feature of this project is that it could provide real time measurement of the parameter of the system to be monitored. It also indicates the actual setpoint setting of the system parameter selected. The overall concept is to show the capabilities and different features of a programmable logic controller.

CHAPTER ONE

PLC
PROGRAMMABLE LOGIC CONTROLLER

1.1 INTRODUCTION

The introduction of PLC or Programmable Logic Controller in the 1970s has revolutionised the field of automation and process control. In 1977, the Allan Bradley Corporation in America introduced a microprocessor-based PLC. This was based on an 8080 microprocessor, with an extra processor for logic bit instruction at high speed.

Since then the application of PLC has grown tremendously over the years, and more and more applications are being handled by the use of PLC.

The development of PLC was conceived as a replacement for the hard-wired relay and timer logic. Allan Bradley Corporation found that hard wired controls were very tedious and very disappointing. Faults in the program were only discovered after the difficult task of wiring and connecting the relay were finished. Additional wiring and rechecking had to be done again to activate the process.

The use of PLC, provides ease and flexibility in use. The program needs to be checked and entered into the PLC. If there is fault in the program, just the software program is corrected and entered again with no need of rewiring.

A further advantage with PLC is that with a new control system, say an expansion of the same task, it is not necessary to do the wiring again. The program of the other system is just loaded to the new one. A great deal of time and money is saved.

1.2 OPERATION

The PLC operates by examining the input signal from the process through the process input image table. The PLC Memory performs the logic instruction as programmed. An output signal is produced as a result of the operation and is output through the output image table producing an output signal that drives output devices and other process control equipment.

Besides the basic logic operation, PLC has other internal functions such as timers, counters, shift registers and one of the more recent additions is handling analog signal operations.

1.3. APPLICATIONS

PLC is now widely used by manufacturing companies performing sequential operations. Proving itself much superior to the relay logic operation, PLC became the main reason for greater productivity.

The use of PLC has now extended to process control industries because of its capability of handling analog data. This makes the application of PLC very versatile which makes it even more popular.

1.3.1 Some applications of PLC are:

- Material handling
    - - sorting
    - - counting
    - - transporting
    - - stacking

- Packaging
- Building automation
- Process Industries
  - - Dairies
  - - Bakeries
- Traffic engineering
- Power plants

1.4. FEATURES.

1.4.1 Some features of the PLC are:

- Rugged, good immunity to noise
- Modular, plug-in construction allowing easy replacement and addition of units
- Standard input output connection and signal levels.
- Programming language is very easy to understand.
- Easy to program and could be programmed in-plant.

These features give PLC the advantage over the use of relay logic system.

1.4.2 Some of the advantages of PLC over relay logic are:

- ***Less wiring*** - control task is implemented by on/off programming instead of the usual hard wiring.
- ***Greater flexibility*** - changing the control logic simply requires reprogramming as compared to time consuming rewiring and changing basic components.
- ***Low space requirements*** - the unit is very compact requiring very little space.
- ***Wider function range*** - Although the PLC is compact, it is capable of more than open loop controls, handling analog value processing, counter functions and other functions.

- ***Higher speed*** - S5-95U executes more than 1000 binary statements in 2 milliseconds time.
- ***Low power consumption*** - requires a few hundred mA current at 24 volts supply.
- ***Problem-free installation*** - mountings are of the 35 mm standard rails. They can be directly mounted onto walls or supporting plates, and connected to a wide range of power supplies.
- ***Modular expansion capability*** - both modular and compact controllers grow with their task since all of them can be additionally expanded.
- ***Affordable price*** - price is very affordable compared to relay control system. The entry of PLC to the world of automation is no longer associated with high investments.

CHAPTER TWO

SIEMENS PLC SIMATIC S5-95U

2.1 INTRODUCTION

The S5-90U and the S5-95U Simatic PC are the most compact and economical control systems in the S5 family. They best suit small and simple automation tasks. They are highly efficient and very flexible compared to the conventional relay logic system.

The S5-95U is good for solving complex task especially analog value processing. It has 16 digital inputs, 16 digital outputs, 8 analog inputs and one analog output. It also has 4 interrupt functions, and 2 counter inputs aside from the built-in timers and counters. Even though it is so small with a dimension of (120 x 100 x 80) it is very powerful.

It has modular expansion capability, so expanding the system by adding input and output is not a problem. It is robust and all expansion modules are small and easy to use. They are also ruggedly constructed, not susceptible to electromagnetic interference.

2.2 PRINCIPLE OF OPERATION

Figure 2.1 below illustrates the functional units of a Programmable Controller. The following are the major components of the PLC.

2.2.1 Programming Memory (RAM, EPROM, EEPROM)

Programs are made through programmer and are stored in the program memory of the PLC. It is a reserved area in the CPU RAM. Control programs can also be stored outside of the PLC by using EPROM or EEPROM sub module.

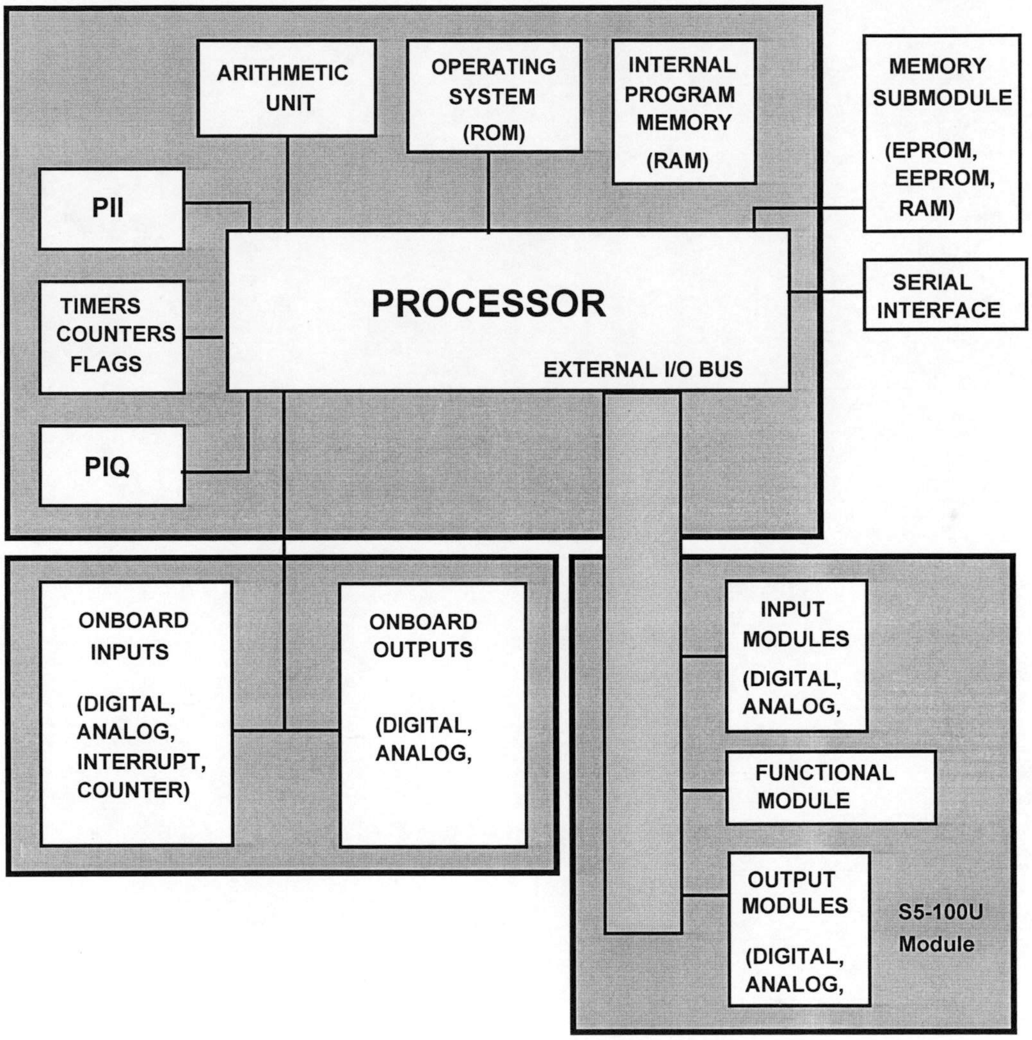


Fig. 2.1 Functional Units of the Programmable Controller

2.2.2 OPERATING SYSTEM (ROM)

This contains the system program that executes the user's program. It also manages the inputs and outputs, how the memory is divided and how the data of the PLC is handled. The operating system which is the one initially called before executing the actual user's program is fixed and cannot be changed.

2.2.3 PROCESS IMAGES (PII, PIQ)

There are reserve areas in the CPU RAM where the signal state of the input and the output are stored. Process Images tell the CPU the condition of the inputs and the outputs in the system.

2.2.4 SERIAL INTERFACE

PLC unit and Programmer unit are connected by the serial interface (cable connection). It is also possible to connect this equipment to local area network using this interface for SCADA or system control and data acquisition.

2.2.5 PROCESSOR

The processor calls the statement in the program memory in sequence to execute them depending on the control program. It processes the instruction from the process image table taking into consideration the status of the timers, counters and flags.

2.2.6 TIMERS AND COUNTERS

The CPU has internal timers and counters that the control program can use. The control program can set or reset timers and counters. A reserve area in the RAM memory stores the time and count values.

2.2.7 FLAGS

An area in the RAM memory where intermediate result can be stored as flag. Flags are addressed by bit, byte, or word.

2.2.8 EXTERNAL I/O BUS

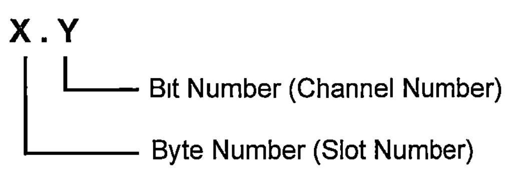
External signals that are exchanged between the CPU and the S5-100 expansion modules are connected by the I/O bus.

2.3 ADDRESSING.

The S5-95U has two types of inputs and outputs. The input/output located on the PC itself are called "onboard" I/Os. The expansion module S5-100U are called external I/Os. Address assignment depends on which slot the expansion module is attached. The module is immediately assigned a slot number and consequently a fixed address in the process image table. Onboard I/Os have fixed address since they occupy no slot.

2.3.1 DIGITAL MODULES.

Digital modules can be plugged in the slot 0 through 31. Digital address uses the following form:



Example Program Segment: **I 0.2**

This is an address of a digital input (**I**) taken at channel 2 (**2**) from an expansion module connected at slot 0 (**0**).

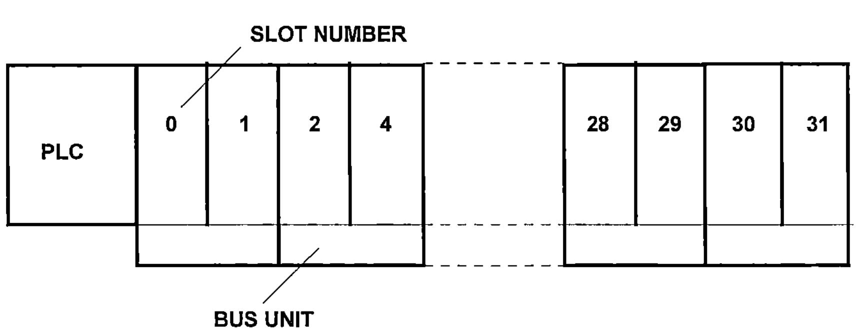


Fig 2.2 Slot Numbering of the S5-95U PLC

2.3.2 ANALOG MODULE

The analog module can be plugged into slot 0 through 7 and the allowed address space extends from 64 bytes to 127 bytes. Each slot has a reserve address of 8 bytes (or 4 words).

Example Program Segment: **T QW 72**

T is a transfer operation. QW 72 is the analog address of the analog output having 2 bytes or a word of data (byte 72 and byte 73) taken from channel 0 of a 4 channel analog output module connected to slot one (1).

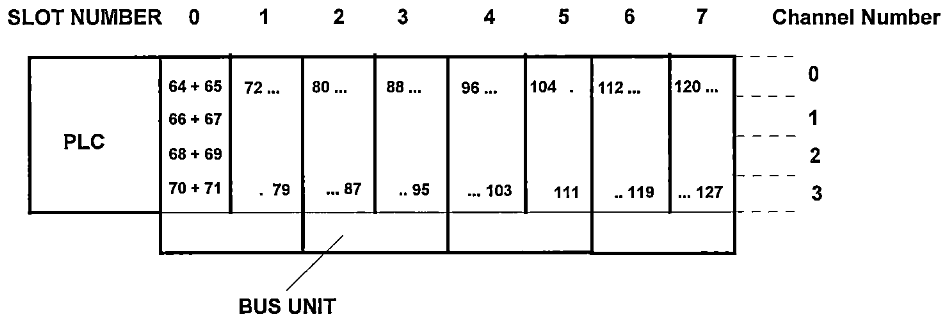


Fig 2.3 Address Assignment for Analog ModulesI of the S5-95U PLC

2.4 ACCESSING INPUT AND OUTPUT

Input and output data are access through the process image table. During data cycle, data is read into the PII. This data is used in the control program. After the evaluation and execution of the control program, the data is written into the PIQ to be transferred to the output module.

Input and output are expressed by the operand identifier as I, IB, and IW for inputs and Q, QB and QW for outputs

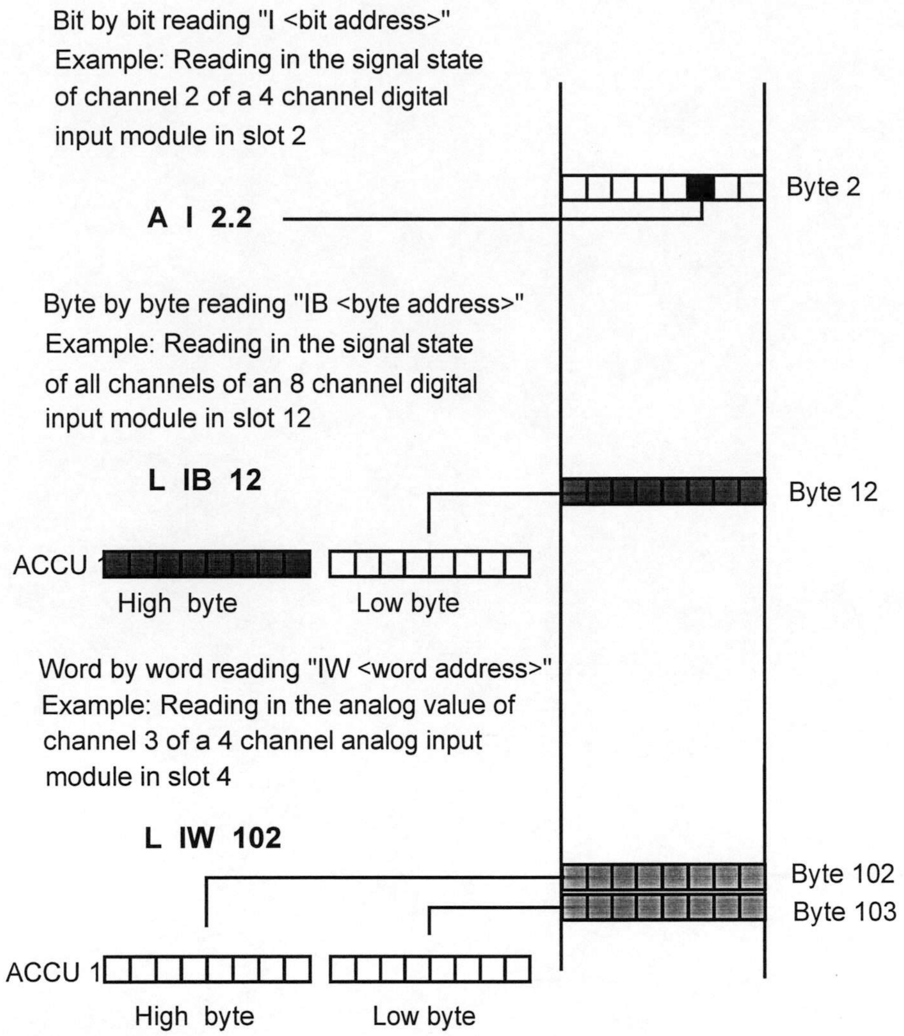


Fig. 2.4 Accessing the Process Input Image Table (PII)

Accessing the process image output table operate very much like as the PII, it is just the reverse. Depending on the operation, the data generated after the processing is written or transferred to the PII memory.

CHAPTER THREE

PROGRAMMING USING STEP 5

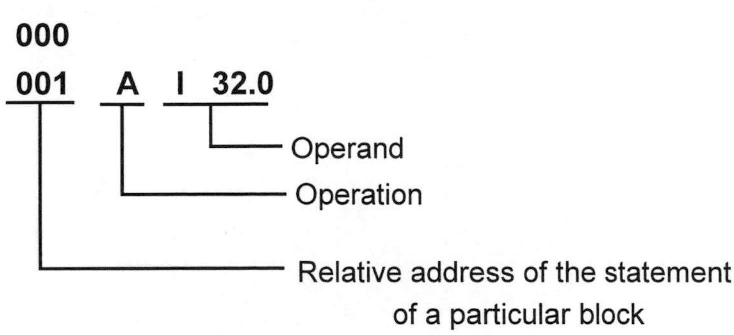
3.1 REPRESENTATION

The Siemens PLC S5-95U uses Step 5 programming language a control program written by Siemens using 3 methods of representation. It uses the programmer PG 685 or a software in a personal computer to write a program to the PLC.

The three different methods of representation are:

3.1.1 STATEMENT LIST (STL)

Represent the program in operation mnemonics. STL has a format of:



3.1.2 LADDER DIAGRAM (LAD)

Graphical representation of control program using circuit diagram symbols.

3.1.3 CONTROL SYSTEM FLOW CHART (CSF)

CSF uses graphic symbol to represent logic operation.

The last two methods of representation cannot represent supplementary and system operations such as special function blocks. Both are just used in representing basic operations (ie. logic operations, timer operation, etc.).

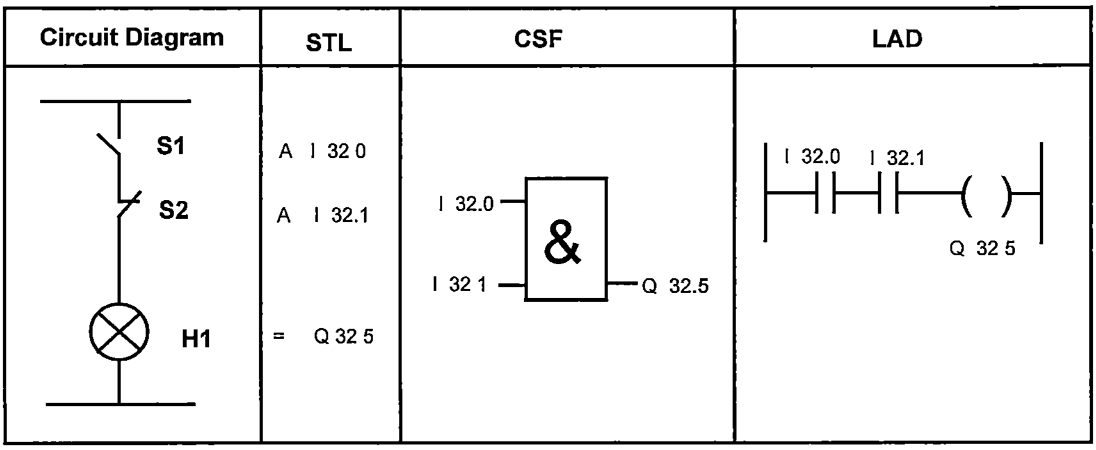


Fig. 3.1 Comparison of the Three Types of Representaiton

3.2 OPERAND AREAS

The STEP 5 programming language has the following operand areas.

I	**(inputs)**	Interfaces from the process to the programmable controller
Q	**(outputs)**	Interfaces from the programmable controller to the process
F	**(flags)**	Memory for intermediate results of binary operations
D	**(data)**	Memory for intermediate results of digital operation
T	**(timers)**	Memory for implementing timers
C	**(counters)**	Memory for implementing counters
P	**(peripherals)**	Interfaces from the process to the programmable controller

K	**(constant)**	Defined numeric values
OB, PB,	**(blocks)**	Program structuring aids
FB, DB,	**(blocks)**	Program structuring aids
SB	**(blocks)**	Program structuring aids

3.3 OPERATIONS

3.3.1 BOOLEAN LOGIC OPERATIONS

3.3.1.1 *AND Operation*

AND Logic operations perform circuits connected in series. The signal state of the operand is ANDed after the operation A is scanned.

Example:
```
A I 32.0
A I 32.1
= Q 33.7
```

If the signal state of I 32.0 is "1" and I 32.1 is "1" and the operation is AND, the output Q will be "1".

3.3.1.2 *AND NOT Operation*

Scan operand for "0" and combine with the RLO through the logic AND.

3.3.1.3 *OR Operation*

OR Logic operation performs a circuit connected in parallel. The signal state of the operand is ORed after the operation OR is scanned.

Example:
```
O I 32.2
O I 32.3
= Q 33.6
```

If the signal state of I 32.2 is "1" and I 32.3 is "0" and the operation is OR. The output Q will be "1".

3.3.1.4 *OR NOT Operation*

Scan operand for "0" and combine with RLO through logic OR.

3.3.1.5 *COMBINED AND - OR Operation*

Equivalent to series- parallel circuit connection. Parenthesis is used to combine the operation.

3.3.2 SET AND RESET OPERATION

Set/Reset operations store the result of logic operations (RLO) formed in the processor. The store RLO represents the signal state of the addressed operand. Table 3.1 below shows the overview of the set/reset operation.

Operation	Meaning
S	**Set** The first time the program is scanned with RLO = 1, signal state "1" is assigned to the addressed operand. An RLO change does not affect this status.
R	**Reset** The first time the program is scanned with RLO = 1, signal state "0" is assigned to the addressed operand. An RLO change does not affect this status
=	**Assign** Every time the program is scanned, the current RLO is assigned to the addressed operand.

Table 3.1 Overview of the Set/Reset Operations

Example:

```
A    I  32.5
S    Q  33.0
A    I  32.6
R    Q  33.O
NOP  0
```

In the example input I 32.5 sets the flip-flop Q 33.0 (signal state "1"). If the signal state of I 32.5 changes to "0" the output state of the flip-flop is maintained at "1", the signal is latched. An input signal of "1" to I 32.6 will reset the flip flop to "0"

3.3.3 LOAD AND TRANSFER OPERATION

The tasks of Load and Transfer are :

Exchange information between various operands
Prepare time and count values for further processing
Load constant for program processing

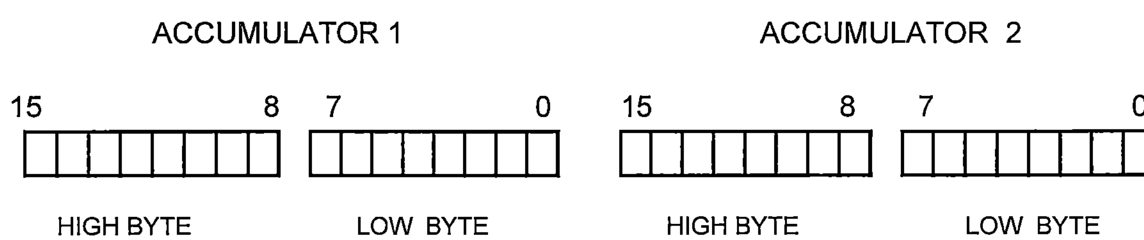


Fig. 3.2 Accumulator 1 and 2 of PLC

The accumulators are special registers that serve as temporary storage in the programmable controller. There are two accumulators in the PC, ACCU 1 and ACCU 2.

3.3.3.1 *LOAD Operation*

The operand contents are copied into ACCU 1 regardless of the RLO. The RLO is not affected. During loading, information or data is copied from a memory area into ACCU 1. Previous content of ACCU 1 is shifted to ACCU 2.

3.3.3.2 *TRANSFER Operation*

The contents of ACCU 1 are assigned to an operand regardless of the RLO. The RLO is not affected. During transfer operation, the information from ACCU 1 is copied into the addressed memory area into the PIQ.

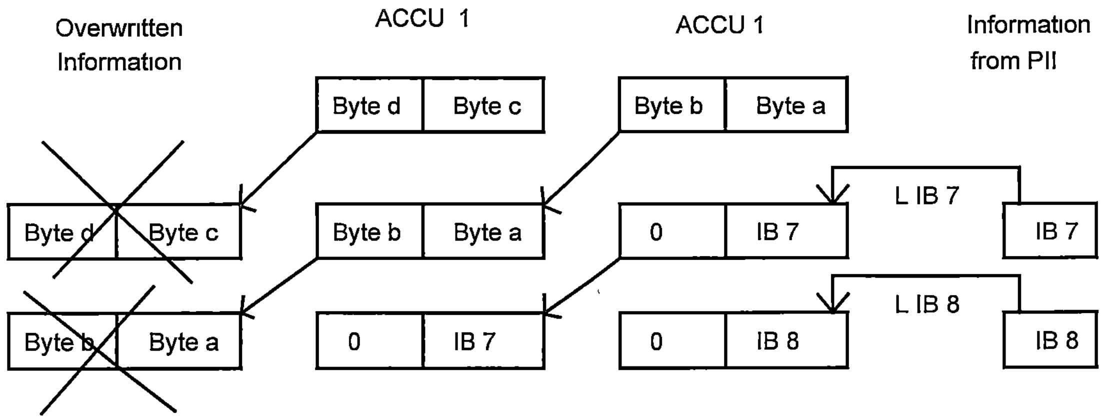


Fig 3.3 Execution of LOAD Operation

3.3.4 TIMER OPERATION

To implement and monitor chronological sequences, the program uses timer operations. There is a total of 6 timer operations, they are:

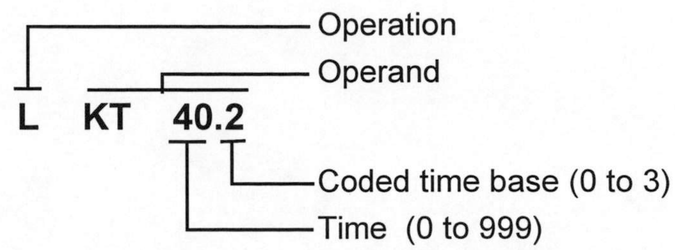
SP	Pulse Timer
SE	Extended pulse time
SD	On-Delay timer
SS	Stored On-Delay timer
SF	Off-Delay Timer
R	Reset timer

Each timer have each application and use. Depending on your program configuration you can make any timing sequence from any of the six timers.

3.3.4.1 *Loading Time*

Internal timers are called during timer operations. When timer operation commences, the word in ACCU 1 is used as the time value, so you must load the time value to ACCU 1 before calling the timer operation. This could be done by :

Example:



Key for Time base:

Base	**0**	**1**	**2**	**3**
Factor	**0.01 s**	**0.1 s**	**1 s**	**10 s**

There are 128 internal timers inside the PC (0 to 127 for S5-95U). So for the example above, the ACCU 1 is loaded with timer constant of 40 seconds since the coded time base used is 2. The best operand to use is KT since this is already in decimal form. Though you can also use DW, IW, QW, and FW can also be used but in BCD form so that it will evaluated.

3.3.5 COUNTER OPERATION

Counting and other counting related jobs are handled by the counter operation of the programmable controller. The counting has a range from 0 to 999. There is a total of 128 internal counters that could be called (C 0 to C 127). Table 3.2 provides an overview of the counter operations.

Operation	Meaning
S	Set Counter The counter is set on the leading edge of the RLO.
R	Reset Counter The counter is set to zero as long as the RLO is "1".
CU	Count Up The counter is incremented by 1 on the leading edge of the RLO. When the RLO is "0" the counter is not affected.
CD	Count Down The count is decremented by 1 on the leading edge of the RLO. When the RLO is "0" the count is not affected.

Table 3.2 Overview of the Counter Operation

3.3.6 COMPARISON OPERATIONS

The comparison operation simply compares the content of the accumulators. In this operation, the contents of the two accumulator are not changed. The values to be compared are loaded in succession into the accumulator and then the comparison operation is performed.

Example:

```
L     C  1
L     KC 005
! = F
S     Q  33.5
```

In the example, the present count of counter 1 is loaded to ACCU 1. In the next statement a constant with a value of 5 is loaded to ACCU 1, where the previous content of ACCU 1 is transferred to ACCU 2. With the execution of " ! = F " the two ACCU are compared and if they are equal, digital output Q 33.5 will be set to "1".

The different comparison operations are:

Operations	Meaning
! = F	Compare for "equal to "
> < F	Compare for "not equal to"
> F	Compare for "greater than"
> = F	Compare for "greater than or equal to"
< F	Compare for "less than"
< = F	Compare for "less than or equal to"

Table 3.3 Overview of the Comparison Operation

3.4 PROGRAMMING STRUCTURE

There are two types of programming that can be used in programming S5-95U Siemens PLC.

1. Linear
2. Structured

3.4.1. Linear Programming

Programming simple operation using one block. Simple automation jobs can be programmed using linear programming. Since it is only one block, it uses one organisational block OB 1. The PLC scans the block cyclically.

3.4.2. Structured Programming

For complex tasks, it is advisable to divide the program into an individual self-contained program (block). This makes the programming simple, easy to change and easy to work with.

Five Block Types used in STEP 5 Programming

1. **Organisational Block** - The first block called by the operating system. It manages the control program.
2. **Program Block** - arranges the control program according to functional and technical aspects.
3. **Sequence Block** - a special block that programs sequence control. It is similar to a program block.
4. **Function Block** - a special block used for frequently recurring or complex program parts. They have an extended set of operation.
5. **Data Block** - data needed to process a control program can be stored in the data block.

In order to exit one block and jump to another, the program uses the block calls. This enables up to 16 levels randomly to be nested.

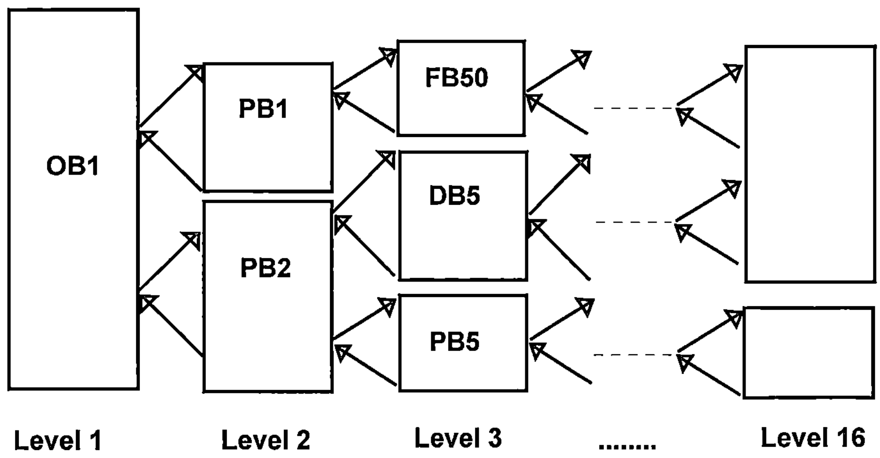


Fig. 3.4 Example of Nesting in Structured Programming

3.5 JUMP OPERATION

Another advantage of structured programming is the use of the jump operation. The jump operation enables the movement from block to another during processing. There are seven different types of jump operation but the two main types are:

3.5.1. Jump Unconditionally (JU) - this is executed independent of any conditions or regardless of RLO.

A I 32.0	Irregardless of the result of I 32.0 and I 32.1, the
A I 32.1	processing will jump to function block 250.
JU FB 250	

3.5.2. Jump Conditionally (JC) - this is executed if the RLO or Result of Logic Operation is "1". If the RLO is "0" the statement is not executed and the RLO is set to "1".

A I 32.3	In this example, PB 80 will not be executed until the
A I 32.4	preceding statements are "1". JC needs the RLO to be
JC PB 80	"1" in order to be executed.

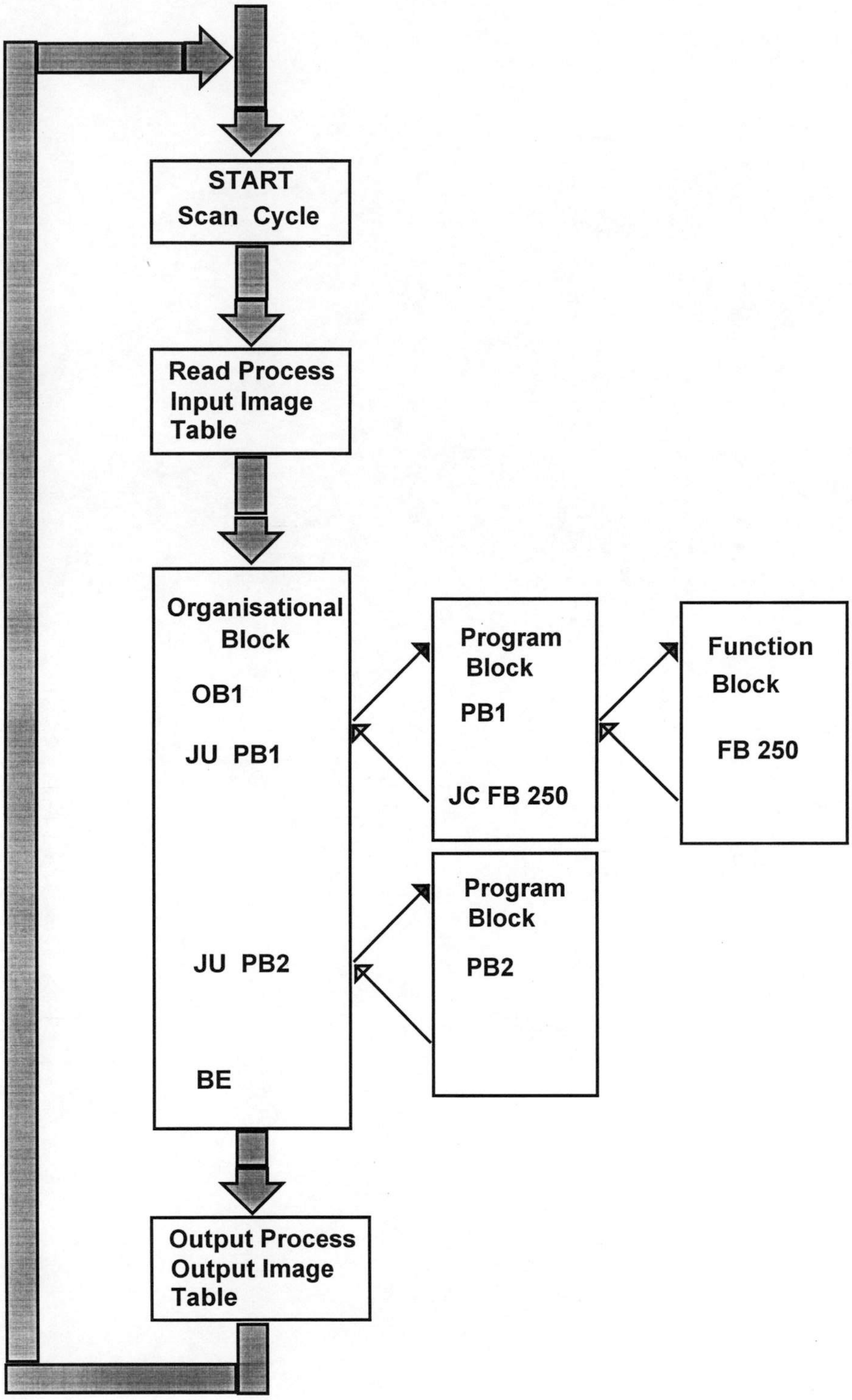


Fig 3.5 Control Program Structure

3.6 ANALOG VALUE PROCESSING

There are a total of eight analog input and one analog output onboard the S5-95U PLC. There is a built-in function block program that allows a direct I/O access call to the program. Once these function blocks are called, the processor executes this specially written sequence of operation (depending on which FB is called ie. FB 250 reads analog value while FB 251 outputs the analog value).

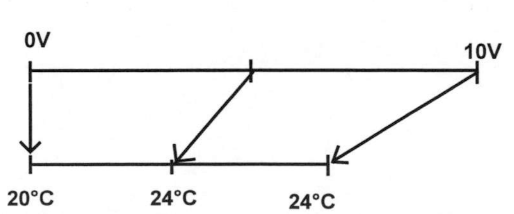
3.6.1 READING IN AND SCALING ANALOG VALUE (FB 250)

Function block FB 250 reads in an analog value from an input channel and outputs a scaled value as specified by the user to XA, an address in the memory which is also to be specified by the user.

Example:

STL			EXPLANATION
		: JU FB 250	
NAME	: RLG :	AE	From the diagram below, the temperature
BG	:	KF = +8	range defined by the user is 20 to 28 °C, the analog
KNKT	:	KY = 0,4	input (IW 40) delivers a nominal value of 0 to 10
OGR	:	KF = +280	volts. If UGR or lower limit is assigned +200
UGR	:	KF = +200	and OGR or upper limit is assigned with +280
EINZ	:	F 50.0	then the temperature is scaled to output XA at
XA	:	FW 130	1/10 ths of a degree. The value is stored as a
FB	:	F 120.0	fixed point number in FW 130.
BU	:	F 121.0	
	:	L PW 40	Hence FB 250 converts the range 0 to 10 V to
	:	T IW 40	a temperature range of 20 to 28 °C.

Table 3.4 Example FB 250 Reading In and Scaling Analog Value



Nominal range of the analog input

Range defined by the user

Fig. 3.6 Converting the Nominal Range to Defined Range

PARAMETER	EXPLANATION	ASSIGNMENTS
BG	Slot Number	8 (Onboard I/O) 0-7 (External I/Os)
KNKT	Channel Number Channel Type	x, y x = 0 to 7 y = 4 (Unipolar)
GR	Upper Limit of Output Value	-32767 to +32767
UGR	Lower Limit of Output Value	-32767 to +32767
EINZ	Single Scan	triggered with signal state "1"
XA	Output Value	Scaled Analog Value
FB	Error Bit	'1" if an illegal channel number or slot number of channel type
BU	Range Violation	"1" if normal range is exceeded

Table 3.5 Function Block 250

3.6.2 OUTPUTTING ANALOG VALUES (FB 251)

When FB 251 is called on the programmer, it outputs the analog value of the assigned parameter. In the example, FW 130 contains the fixed point number that FB 250 calculated in the previous example. The number is then converted to the rev/min setpoint in FB 251.

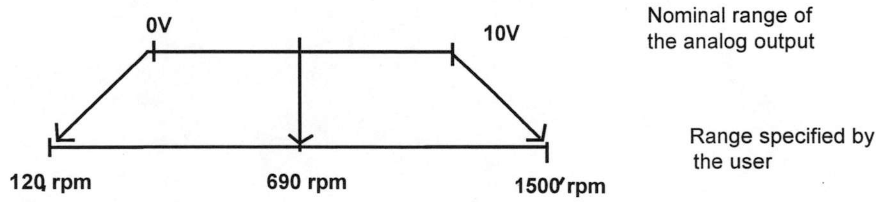


Fig. 3.7 Transforming the Specified Range to Nominal Range

STL			EXPLANATION
	:	JU FB 251	
NAME	:	RLG : AA	In this example, a speed setpoint is to be output
XE	:	FW 130	in the range of 120 to 1500 rev/Min. If the OGR
BG	:	KF = 8	or the upper limit is assigned the value of 1500
KNKT	:	KY = 0,1	and the UGR or lower limit is assigned with 120
OGR	:	KF = +1500	the set point is specified in direct rev/Min. The
UGR	:	KF = +120	range 120 to 1500 rev/Min is converted to output
FEH	:	F 120.1	range of 0 to 10 V.
BU	:	F 121.1	

Table 3.6 Example of Calling FB 251 Outputting Analog Values

PARAMETER	EXPLANATION	ASSIGNMENTS
XE	Analog value to be output	Input value in the UGR to ORG range
BG	Slot number	8 (Onboard I/O)
KNKT	Channel number Channel type	x,y x = 0 (for Onboard I/Os) y = 0 (Unipolar representation)
OGR	Upper limit of output value	-32767 to +32767
UGR	Lower limit of output value	-32767 to +32767
FEH	Error in the limit value setting	"1" if UGR = OGR, for invalid channel or slot number or channel type
BU	Input value exceeds UGR or OGR	'1" if XE is outside the range
BU	Range violation	"1" if normal range is exceeded

Table 3.7 Function Block 251

3.7 USING THE PG 685 PROGRAMMER

3.7.1 INTRODUCTION

The following are step-by-step instructions for using the PG 685 programmer. The first is how to get into the LAD CSF and STL Programming Package of Step 5. Familiarisation with the different function keys of the programmer is very important.

1. Turn on the 24 V power supply of the PLC (make sure that the interface cable is secured).

2. Switch on the S5-95U PLC. The PLC should be in **STOP mode** (ie. the **RED STOP LED** should be on).

3. Turn on the SIMATIC S5 PG 685 PROGRAMMER.

4. Type **S5** by the prompt and then press return. **PACKAGE SELECTION menu** will appear on the screen. Move the cursor to the **LAD, CSF, STL OPTION** by pressing the arrow key. Press **F1** to select the **PACKAGE.** The **PRESETTING menu** will then appear on the screen (Refer to the figure overleaf)

5. The cursor is at Program File by default.
   Type B: **filename**
   where filename is the name of the program to be created or opened.

6. Move the cursor to **REPRESENT** option using the unshaded arrow. Press **F3** to select the type of representation (the option are LAD, CSF, or STL). Then select **STL.**

7. Move the cursor again using the unshaded arrow and go to **OP. MODE,** skipping the other field options. Use **F3** to toggle the mode on (make sure that the interface cable is secured). This enables a direct connection to the PLC and programs may be transferred and run on the PLC while being monitored by the programmer.

8. Enter all the presets by pressing **F6 (Enter)**. This brings up **FCT SELECTION** mode.

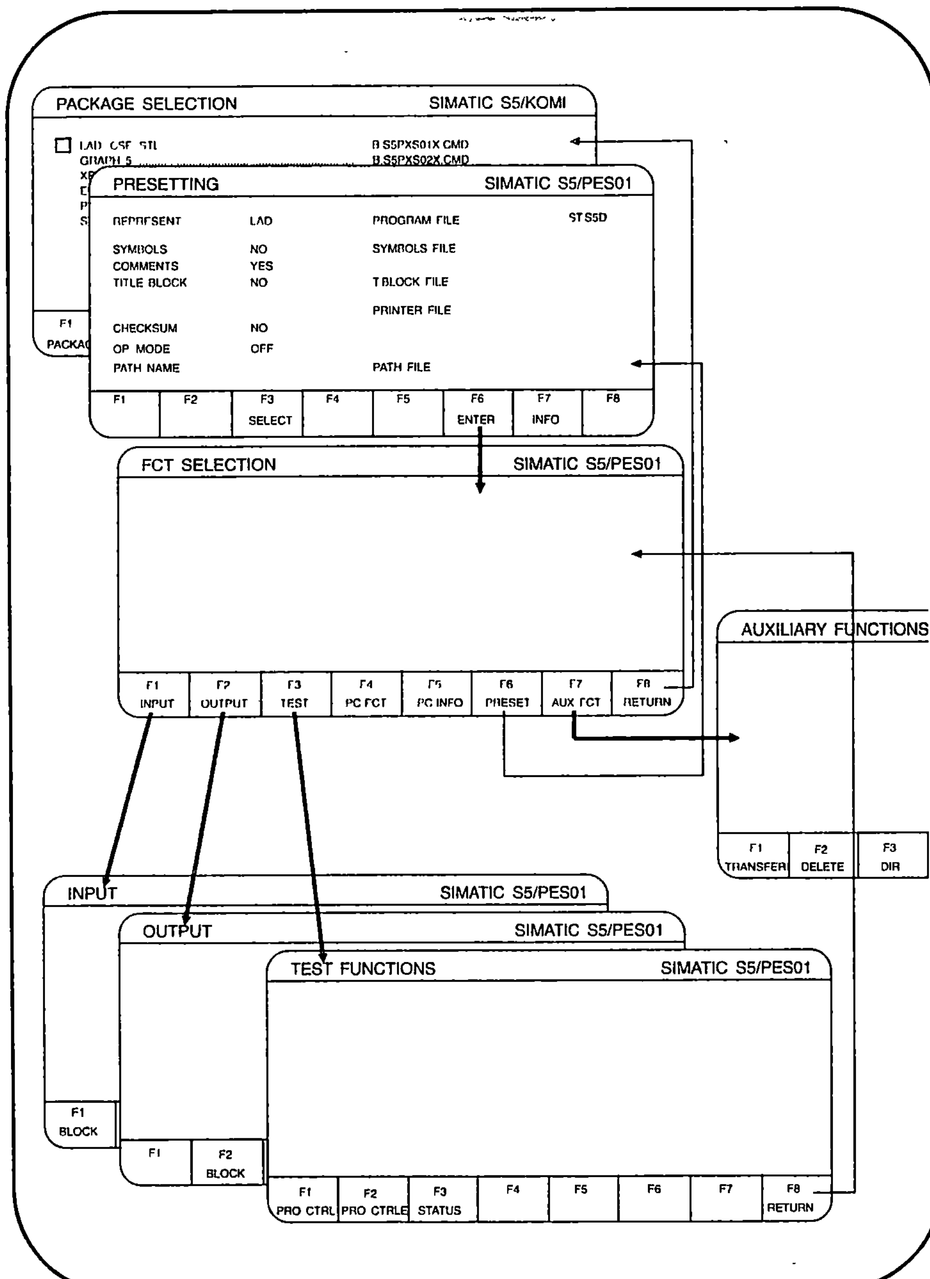


Fig. 3.8 Step 5 Programming Package

9. Press **F7 (Aux. Fct.)** and then
F6 (Prog File). This asks you the name of the program to use or consult.

F3 (Dir). This allows the directory of blocks of the selected program to be seen. It will ask from what directory source. There are two options

1. PC - meaning directory of blocks stored in the PLC
2. FD - meaning directory of blocks on the preset program file.

Source:	**PC**	type PC then press the insert key if there is something programmed in the PC.
	FD	type FD then press the insert key if a program file has been selected.

10. Block address list will display the listings of all the blocks used on that particular program. To see one of these blocks, exit the **AUX.FCT** screen by pressing **F8 (Return).**

11. In the **FCT. SELECTION** screen press **F2 (OUTPUT)** then **F2 (BLOCK)**. This brings up the output mode and by pressing **(BLOCK)**, a block is outputted. A prompt will ask for the output device and block.

OUTPUT DEVICE: **PC** BLOCK: **PB 1**

Type **PC** then **PB 1** then press the Insert Key (assuming there is something in the PC). What will appear is the program in STL that is programmed in PB 1 in the PLC. If FD is typed on the output device, what will appear is the PB1 program on the present program file that has been selected.

3.7.2 WRITING A SIMPLE PROGRAM.

1. From **FCT SELECTION** screen (*Press F8 [Return] if on the OUTPUT screen*), Press F7 (AUX FCT) to go to **AUXILIARY FUNCTIONS** screen, then press F6 (PRG FILE), this will prompt to FD or present Program File. Type

B: FIRST

then hit return, which will bring you back to Auxiliary FCT screen.

2. Press again **F8 (RETURN)** to bring back **FCT SELECTION**.

3. To write a program press **F1 (INPUT)** then press **F1 (BLOCK)**. The programmer will ask which Input Device. If PC is typed it will write directly to the PLC, but if FD is typed, it will write to the present program file. Type

   INPUT SOURCE : **FD** BLOCK : **PB1** then press Insert.

4. Now the program can be written. The program will be written from the example on the previous page.

   : A I 32.0
   : A I 32.1
   := Q 33.5
   : BE

   after hitting the return, the **FCT SELECTION** screen will be displayed.

5. To test whether the program has been written, press **F2 (OUTPUT)** then **F1 (BLOCK)**. It will ask for the Output Device and Block. So type

   OUTPUT DEVICE: **FD** BLOCK: **PB1** then press Insert.

6. What will appear on the screen is the program just entered. To change to other types of representation, press **F7**, which will change to **LAD** then **SCF**. At this moment it is not possible to check if the program is working until it has been transferred to the PLC.

3.7.3 TESTING THE PROGRAM

1. Before transferring the program to the PLC the Overall Reset must be performed. This can be done by the following procedures.
   - Put the "RUN/STOP" switch to STOP position. RED LED must be on.
   - Remove the battery.

- Set the "ON/OFF" switch to "0".
- Set it back to "1" or ON position.
- Insert back the battery.

By dong this, all the programs in the PLC are completely erased.

2. Go back to **FCT SELECTION** screen. Press F7 **(AUX FCT)** then F1 **(TRANSFER)**.

3. Prompt will appear asking the transfer source and the destination, so type

TRANSFER SOURCE: **FD** BLOCK: **PB1** DEST: **PC** BLOCK: **PB1**

Press Insert key

This means that transferring the PB1 from the present program file to the PC has taken place.

4. Now to test the program, go back to **FCT SELECTION** screen then press **F3 (TEST)** then **F3 (STATUS)**. What will appear on the screen is the STL that was programmed and status of each statement.

5. If the PLC is properly wired, and connection made on the digital input, the status on the display will change. If the statement is both satisfied **ie.** I 32.0 and I 32.1 are "1", then the output Q 33.5 will then be "1".

CHAPTER FOUR

CASCADED WATER TANK SYSTEM

4.1 WATER TANK SYSTEM

The cascaded water tank system is composed of 3 water tank systems connected in cascade series. Figure 4.1 illustrates the components of each water tank system. Each system has 2 tanks. Tank 1 is used for cold water storage and for recycling water from tank 2, while tank 2 is the one being controlled and monitored. Both level and temperature are kept to a certain set point. Each system has three measured variables, these are:

- Level of tank 1
- Level of tank 2
- Temperature of tank 2

It is assumed that the two tanks have a different purpose. Tank 1 is for general purpose water supply and tank 2 is used in a process requiring a controlled water temperature. Upsets and disturbances to the system are forcibly introduced in order to simulate the operation effectively.

There are five output devices that can be manipulated and controlled in order to reach the process requirement and specification. These are:

- Cold water valve -for cold water inlet
- Hot water valve -for hot water inlet
- Feed pump -for adding cold water to tank 2
- Recycling pump -for recycling water back to tank 1
- Drain/Process pump -for draining and pumping water

***Cold Water Valve*-** cold water is controlled from the water supply by this valve. Pressure from the water main forces itself to tank 1 when the valve is activated.

***Hot Water Valve*-** hot water supply is regulated by this valve going to tank 2. If temperature and level fall from the set point value, then this valve is activated.

***Feed Pump*-** this pumps the cold water from tank 1 to tank 2 providing variation of temperature on tank 2. The actual operation of the pump depends primarily on the control configuration.

***Recycling Pump*-** for operation to be more economical, water from tank 2 is recycled and put back to tank 1. The recycling pump is activated if the temprerature of tank 2 has already been reached while the level is not right yet.

***Drain and Process Pump*-** This pump delivers the water at controlled temperature to the process where it is used whenever it is needed. In some cases it is the draining which simulates disturbance or creates an upset in the system.

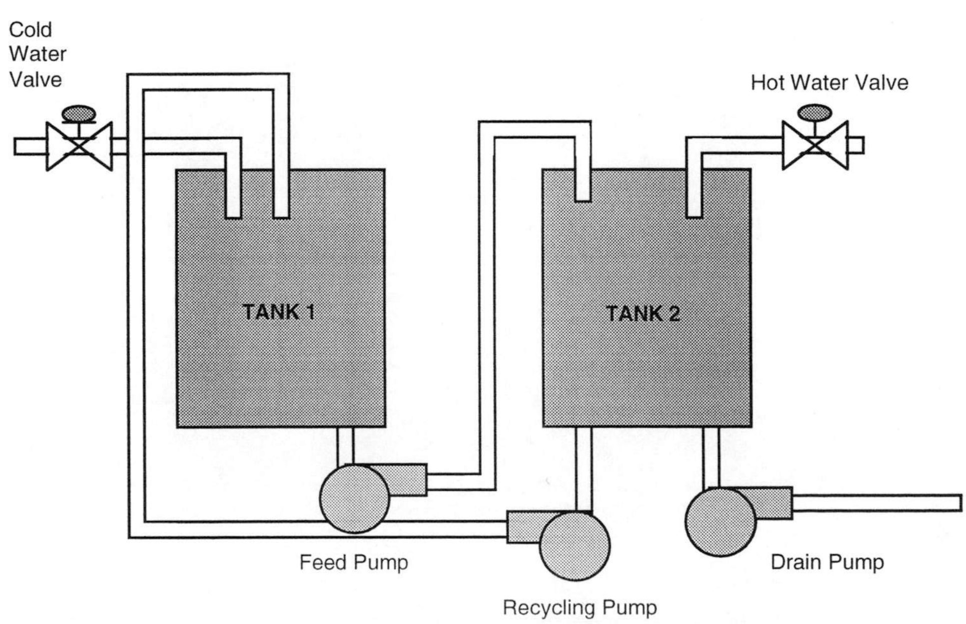


Fig. 4.1 Water Tank System

4.2 System Configuration

Since there are only 3 measured variables, there will be eight possible combinations of situations that could occur in the system. It is best represented by a truth table shown in Table 4.1 below. The other half of the table is the action set to be performed by the output devices corresponding to the given situation.

Temperature Tank 2	Tank 1 Level	Tank 2 Level	Cold Water Valve	Hot Water Valve	Feed Pump	Recycling Pump	Drain
low	low	low	ON	ON	OFF	OFF	OFF
low	low	high	ON	ON	OFF	OFF	ON
low	high	low	OFF	ON	OFF	OFF	OFF
low	high	high	OFF	ON	OFF	OFF	ON
high	low	low	OFF	ON	OFF	ON	OFF
high	low	high	OFF	OFF	OFF	ON	OFF
high	high	low	OFF	ON	ON	OFF	OFF
high	high	high	OFF	OFF	OFF	OFF	OFF

Table 4.1 System Possible Input and Corresponding Output

The designated outputs for each situation are based on the most logical and economical way of bringing the system into equilibrium. Equilibrium or steady state is when the temperature and the level of both tanks are at their set value.

Using the Karnaugh method of simplifying Boolean logic operation, we arrived at the following equation:

$$C = \overline{T}\,\overline{L_1}$$
$$H = \overline{T} + \overline{L_2}$$
$$P = T L_1 \overline{L_2}$$
$$R = T \overline{L_1}$$
$$D = \overline{T} L_2$$

Where:

C -cold water valve
H -hot water valve
P -feed pump
R -recycling pump
D -drain pump

T-temperature
L1-level of tank 1
L2-level of tank 2

Cold Water Valve

	$\bar{L}_1\bar{L}_2$	$\bar{L}_1L_2$	L_1L_2	$L_1\bar{L}_2$
$\bar{T}$	1	1	0	0
T	0	0	0	0

Hot Water Valve

	$\bar{L}_1\bar{L}_2$	$\bar{L}_1L_2$	L_1L_2	$L_1\bar{L}_2$
$\bar{T}$	1	1	1	1
T	1	0	0	1

Feed Pump

	$\bar{L}_1\bar{L}_2$	$\bar{L}_1L_2$	L_1L_2	$L_1\bar{L}_2$
$\bar{T}$	0	0	0	0
T	0	0	0	1

Recycling Pump

	$\bar{L}_1\bar{L}_2$	$\bar{L}_1L_2$	L_1L_2	$L_1\bar{L}_2$
$\bar{T}$	0	0	0	0
T	1	1	0	0

Drain Pump

	$\bar{L}_1\bar{L}_2$	$\bar{L}_1L_2$	L_1L_2	$L_1\bar{L}_2$
$\bar{T}$	0	1	1	0
T	0	0	0	0

Fig. 4.2 Karnaugh Table for the System Configuration

There is a total of nine parameters to be measured, three for each system, and a total of fifteen output devices to be controlled. Since there are only eight (8) analog inputs in the Siemens PLC, it was decided to monitor just the controlled tank, and not the cold-recycling tank.

The output logic equation is then translated into a ladder diagram which is used to program the PLC. The following figure Fig. 4.3 shows the ladder diagram that will perform the operation listed on Table 4.1.

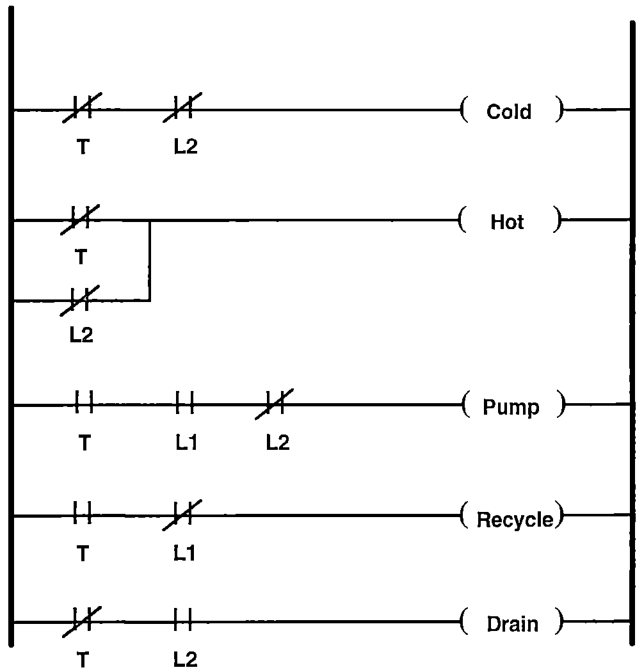


Fig. 4.3 Ladder Diagram that Implement the Operation on Table 4.1

4.3 Operation of Water Tank System

The systems initial condition is assumed to be that all variables are low, meaning that there is no water in tank 1 and tank 2 and the temperature sensor is just measuring the ambient temperature. This condition could be checked on row 1 of Table 4.1. The corresponding output operation is to turn on the cold and hot water valve. Depending on the temperature of the hot water, either the temperature setting is reached first or the level set point of tank 2 is reached. There is a corresponding output action assigned for every situation. Once the level of tank 1 and tank 2 is reached and the temperature of the water in tank 2 equals the setpoint, all the output devices are off.

Supposing a disturbance is introduced into the system either by removing some water from the tank (this could be done by forcibly energising the drain or scooping water from the tank) or letting the water in tank 2 cool down, this will change the condition of the system thus causing a corresponding corrective action.

With the water tanks being cascaded, meaning the drain of the first tank system is fed to the second system, and the drain of the second tank system is fed to the third system. The third system which is the last tank system is the one that is fed to the water drain. With this scheme, it is possible to cause variations of level and temperature.

CHAPTER FIVE

CONTROLLER INTERFACE MODULE

The controller interface module serves as the connection between the water tank system and the PLC. The temperature and level of tank 2 and the setpoint values of the three water tank system are monitored here. The setpoint of the different process variables are all adjusted through this black box.

This controller interface module houses the following blocks:

- -Mode and select switches
- -The display module
- -Signal conditioning unit

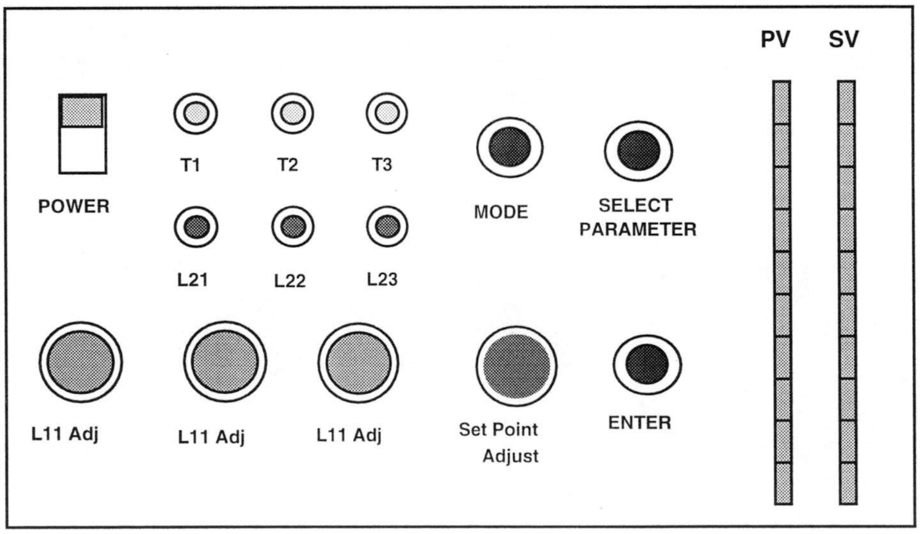


Fig. 5.1 Controller Interface Module

5.1 Mode and Select Switches.

5.1.1 MODE SELECT- this allows the mode of operation of the controller and the interface to be selected.

a. Monitor Mode- this allows monitoring of the real time measurement of the parameter of the system selected. It also monitors the set point setting of that particular parameter.

b. Set Point Adjust Mode- this mode allows adjustment of the set point of the parameter selected and view set point while adjustment is being made.

5.1.2 SELECT PARAMETER- this switch allows movement to the parameter on the system to be monitored or to change the setpoint. There are six selections:

a. T1	- for temperature of water system 1
b. L21	- for level of tank 2 of water system 1
c. T2	- for temperature of water system 2
d. L22	- for level of tank 2 of water system 2
e. T3	- for temperature of water system 3
f. L23	- for level of tank 2 of water system 3

5.1.3 LEVEL ADJUST- There are three level adjust settings, **L11, L12, L13**. These are the set point adjust for all tank 1 in the system. Since the analog input ports of the PLC are limited to 8, it is not enough to measure all the 9 analog data plus one analog set point. So these three parameters are limited and converted to digital data.

5.2 The Display Module.

The display module is made up of bar LEDs. The display is calibrated to give 0% to 100% reading of the parameter of the system, 0% meaning empty and 100% meaning full for level measurement. For temperature measurement, it is calibrated for 0% for 20°C and 100% for 50°C assuming that the operating temperature of the water being controlled is 20° to 50° C.

There are two displays on the box: the **PV** for Process Variable display, which indicates the measurement of the parameter selected, and the **SV** for Set Point Value. It indicates the set point of that selected parameter.

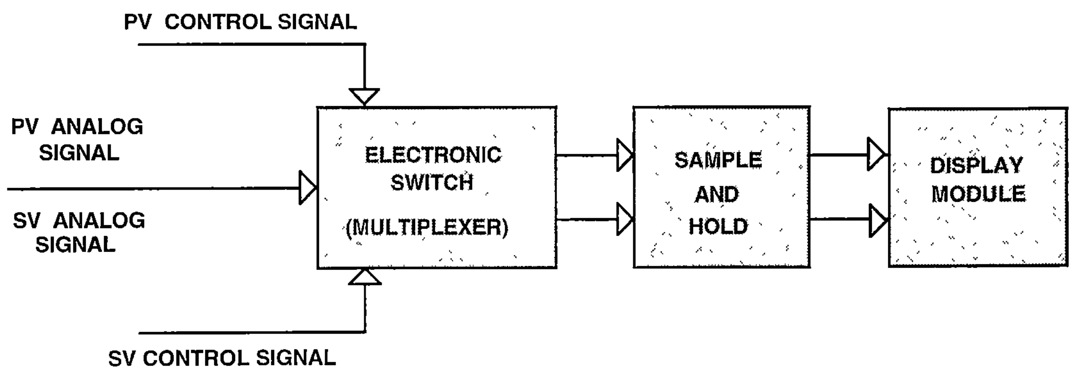


Fig 5.2 Block Diagram of Display Module

5.2.1 OPERATION OF DISPLAY MODULE

There are two analog signals from the water tank system that is to be output or monitored: the PV and the SV analog control signal. These signals are on a separate address in RAM. Since there is only one analog output on the PLC, a multiplexing circuit has been designed. The PV control signal and the SV control signal are generated from the PLC where a short program (PB 46) is added for this purpose.

When PV control signal is "1", (refer to Fig 4.2) the program calls for FB 251 which outputs the data kept in the memory address which keeps the process variable data. A sample and hold circuit holds this analog signal for some time while the signal goes to "0". When this happens, the SV control signal goes to "1", this time outputting the setpoint value data stored in a separate address. Again, this data is sampled and held for some time while PV control signal again goes "1". This process executes continuously as long as the mode is set to 'MONITOR".

If the mode is changed to "SET POINT ADJUST" the SV control signal is set to "1" and the PV control signal is set to "0". Depending on which channel is selected, this forces the display module to output the current setpoint setting, which is kept in a different address in the RAM. The setpoint value can only be changed to a new value if the "ENTER" push button is pressed. Pressing the "ENTER" button sends that analog value to a specific address and then it is stored. Moving the mode switch back to "MONITOR" mode again disables changing the set point.

The six LEDs' on the left portion of the module identify which parameter is being monitored or changed. These LEDs are both used for "MONITOR" mode and for "SETPOINT ADJUST" mode. It makes it easier for the operator or engineer to know which parameter is being monitoring.

5.3 SIGNAL CONDITIONING UNIT

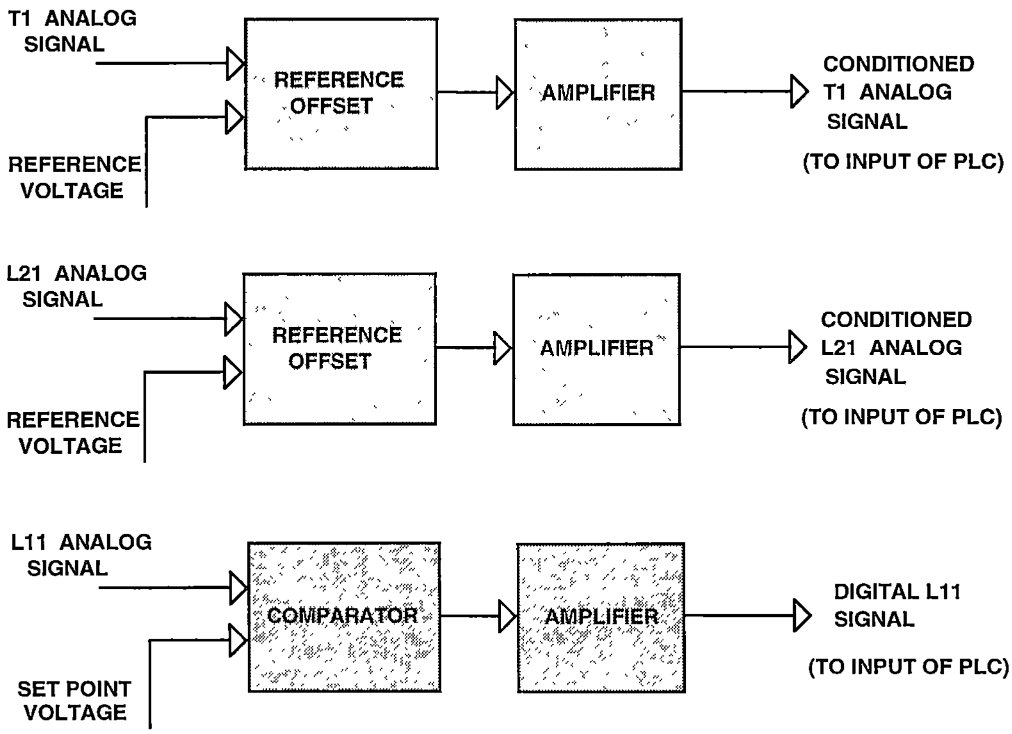


Fig 5.3 Block Diagram of Signal Conditioning Unit

The main function of this unit is to make the signal coming from the system more compatible to the PLC and the display module. Signals coming from the water tank system are raw. These need to be conditioned and calibrated so that the PLC can process them. The reference offset is an operational amplifier that offsets the voltage level of the system with respect to the actual condition of the system. So, if the sensor has an initial reading of 2.3 V if the temperature is 20°C, then it will offset it to 0 V since 20 °C is referred to as 0% of the temperature reading.

With regards to the upper reading of the scale, the amplifier then increases the amplitude level of the analog signal so that the measurement will be standard. So if the maximum voltage that the sensor can provide is 6.7 V for 50 °C process parameter reading, then the amplifier will provide a gain that will make it 10 V corresponding to 100% of the actual reading.

On the PCB there are four adjustable resistors, two for the level of tank 2 and two for the temperature of tank 2 (take note that only tank 2 is being monitored). One for adjusting the offset and the other for adjusting the gain. There are three modules on one PCB, one each for every system.

5.4 OVERALL OPERATION OF CASCADED WATER TANK SYSTEM.

The system is made up of three main block components

- Water Tank System
- Siemens S5-95U PLC
- Controller Interface and Display

5.4.1 WATER TANK SYSTEM

The water tank system as discussed in Chapter 4 provides nine (9) analog reading or signals. These signals are the nine parameters being measured and monitored. These signals are sent directly to the controller interface for signal conditioning and processing. The water tank system block also has the 15 output devices which the PLC controls, five (5) each for every system. These fifteen digital output devices are connected to a separate power supply via electronic switches. The electronic switches are in turn driven or actuated by the PLC based on the programmed operation. Pumps and valve are installed in advance to make up a complete water tank system.

5.4.2 The SIEMENS S5-95U PLC

The PLC sends 15 digital output to the water tank system (see Fig. 5.4). These digital signals are based on the program written to control the system (refer to section 4.2). The other two digital outputs are sent to the controller interface, used as a control signal (PV and SV control signal) for displaying the parameter reading (section 4.1).

The PLC receives six (6) digital inputs from the controller (eg. Mode, Select, Enter and the 3 digital status of the 3 tank 1, L11, L12, L13). These provide information on the task to be performed by the PLC. The six conditioned analog signals from the process tank and the analog 'set point adjust' from the interface controller are connected to the analog input/ output port of the PLC. This model of Siemens PLC S5-95U has 8 analog inputs and 1 analog output. As discussed in section 3.6, there is a special function block FB 250 and FB 251 which reads analog input and converts it into digital information for processing. The FB 251 on the other hand converts the processed digital data back into an analog signal. This analog signal from the PLC is the one used to monitor the system's different parameters.

5.4.3 CONTROLLER INTERFACE AND DISPLAY.

The nine analog signals from the system are conditioned through the Signal Conditioning Unit (SCU). The outputs of the SCU are the six (6) calibrated analog signals from the system, T1, T2, T3, L21, L22, and L23. There are six (6) digital signals going to the digital input of the PLC. These are: mode, select, and enter pushbutton switches and the three digital signals signifying the state of tank 1, L1, L2, and L3. These signals are generated using a voltage comparator. A separate setpoint adjust knob is allocated for tank 1 of each system. This is done as mentioned earlier because there is a limited number of analog input available.

The six analog signals together with the analog set point adjust are passed to the PLC for processing, while the 3 digital signal are combined with the three switches are connected to the digital input of the PLC.

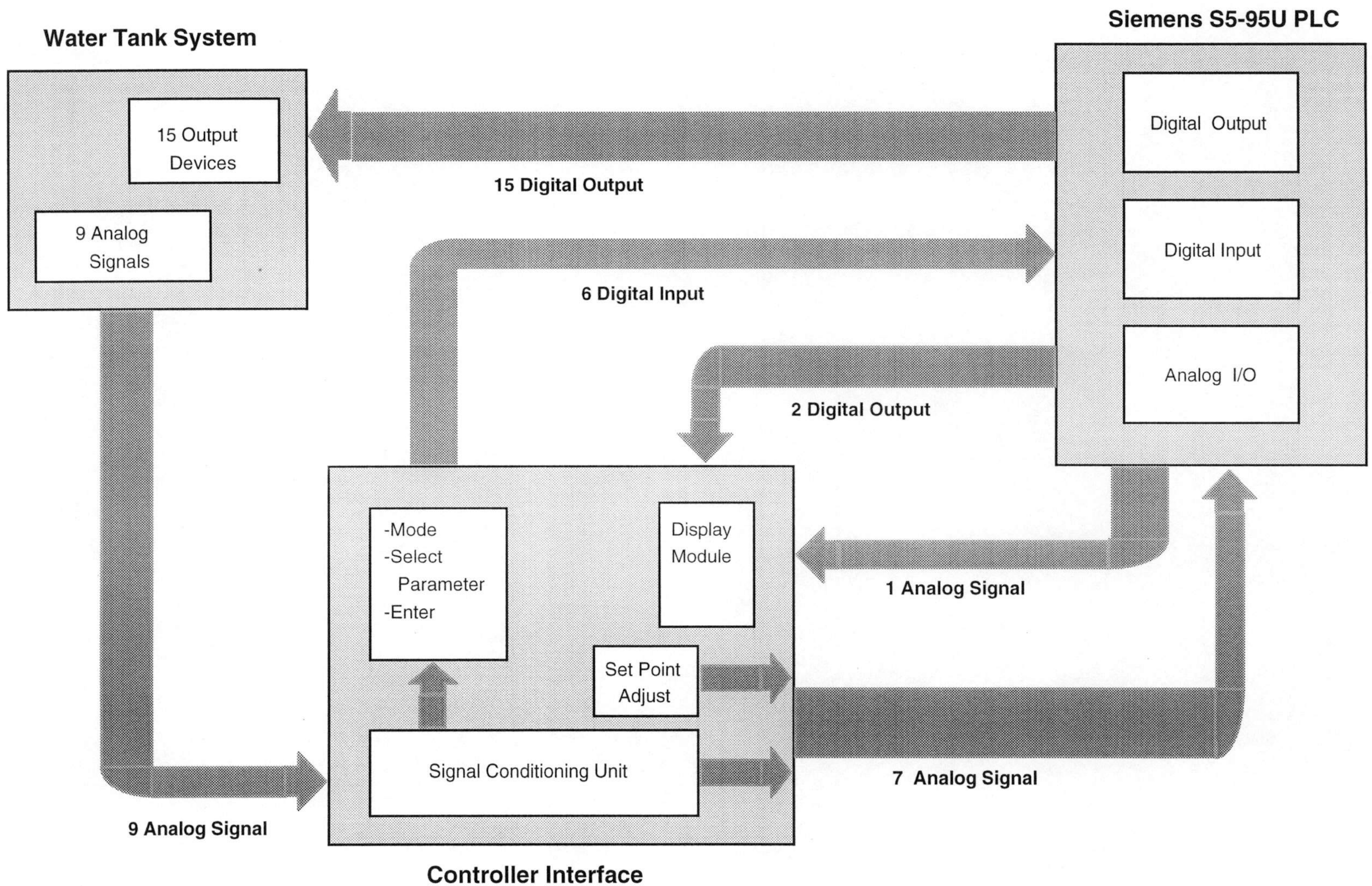


Fig 5.4 Overall opertion of the Cascaded Water Tank System

5.4.4 OPERATION.

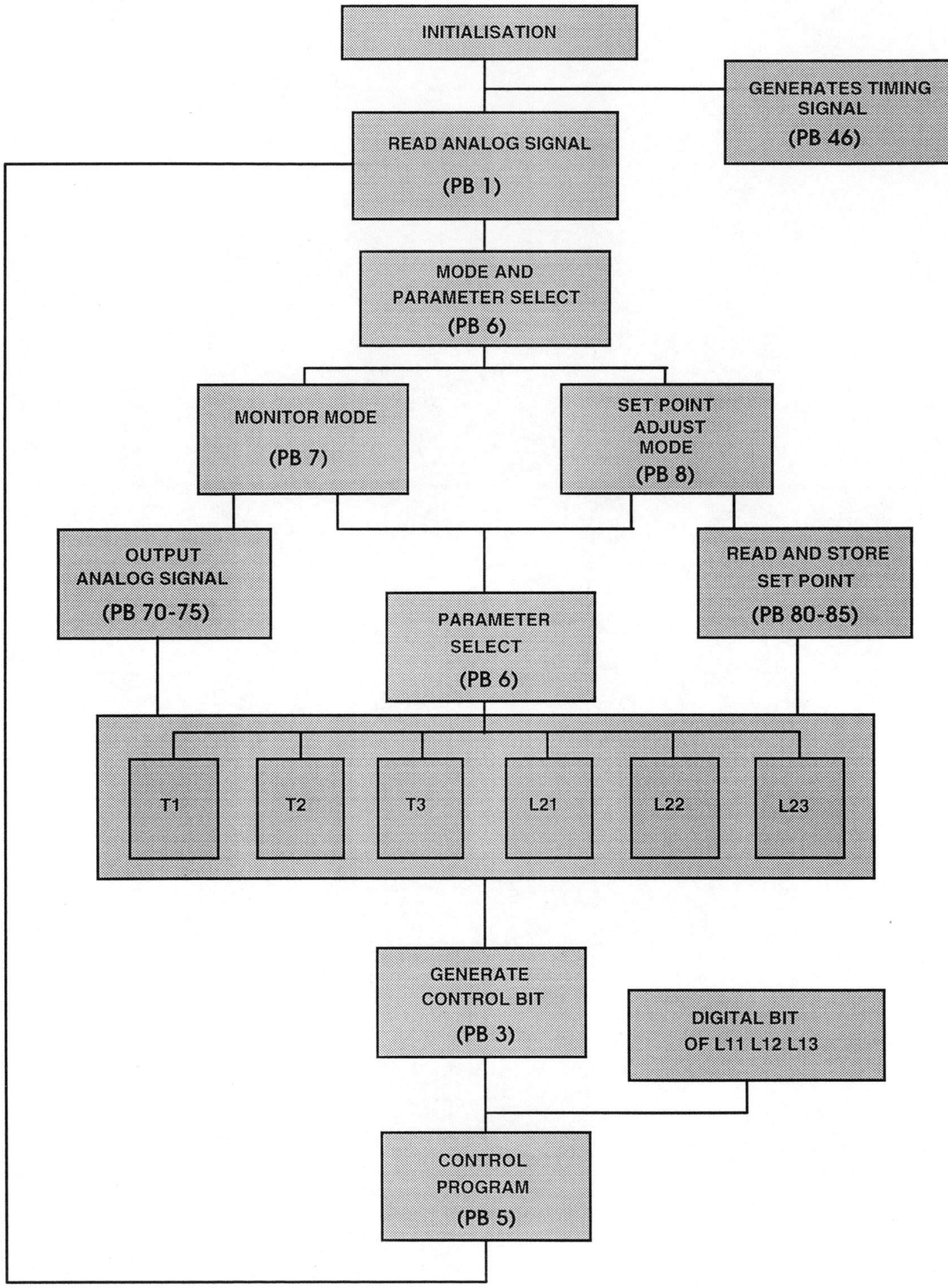
Once all the equipments are set up, the program can be entered into the PLC. The process variable (PV) analog signals from the system are connected to the controller interface module through a wire harness. These signals are calibrated to provide standard voltage level for the PLC to process. The SCU also produces a digital signal which indicates the status of tank 1 in the system. The analog signals are scaled and sampled and are held in a RAM address of the PLC. When the operation is on "MONITOR" mode and a parameter has been selected, the program calls for this address and outputs it in the analog output port of the PLC. This signal is then fed to the display module of the interface for display.

The set point value (SV) is stored in a different memory location in the PLC. This is being accessed alternately with the process variable (PV) by the PLC for display if the mode is in "MONITOR" position. The two control signals makes the outputting of the Process Variable (PV) and the Set Point Value (SV) in a single analog output port, possible.

The "Mode" and the "Select Parameter" provides initial information on what task is to be performed by the PLC. If it is on "ADJUST SETPOINT" mode, the sequence of reading the PV and SV is temporarily interrupted. Instead, the PLC reads the analog input on channel 7 of the analog input port. This is directly connected to a variable voltage divider that sets the value of the setpoint. This analog value is just scaled and passed to the PLC but not stored. It will not be stored until the "ENTER" pushbutton is pressed. The "Enter" locks the set point value in a specific address in the PLC's RAM.

Once all the information is scanned and placed in its respective addresses, the PLC processes these data and a digital output combination is generated. All the digital outputs except one are directly connected to the output devices in the system. These digital signals turn on and off the electronic switches that drive the output devices from a separate power supply.

5.5 BLOCK DIAGRAM OF CASCADED WATER TANK SYSTEM



5.6 BLOCK OPERATIONS OF THE CASCADED WATER TANK SYSTEM

PROGRAM BLOCK 1

Program block 1 reads the analog signal from the analog input port of the PLC. Channel 0 to channel 5 are the six channels used in this program block to read the six analog signals from the water tank system. It uses the FB 250, a special function block for reading analog signal. This analog signal is converted to digital data so that it could be stored and handled by the PLC. The digital information is stored in the temporary register called flag (Flag Word FW- since it is two byte long)

PROGRAM BLOCK 46

This program block generates a control pulse sent to the interface module used for monitoring the process variable and the set point value.

PROGRAM BLOCK 3

Program block 3 generates the status bit that is used in controlling the water tank. The measurement of the process variable stored in a register say FW 10 is compared to the set point value stored in another register, say FW40 (assuming parameter T1 is selected). These two values are compared (eg. greater than or equal to operation) and a status bit is generated, high if it is or low if it is not.

PROGRAM BLOCK 4

This program block allows the user to view the set point while it is being adjusted. It first determine which parameter is selected, and then jumps to PB 88 that does the reading of the analog input port and then outputs it to the output port.

Another part of this program block is the storing of the set value to a selected register. It requires the "Enter" signal to actually store the data.

PROGRAM BLOCK 6

This program block toggles the mode bit depending on the position of the mode switch. It also produces the flag bit for the parameter selected . It uses a count down counter (another feature of PLC) to perform this program block. Depending on the count of the counter, it is compared to a constant and then produces a parameter bit.

PROGRAM BLOCK 88

Reading the set point value and outputting it for display is performed by this program block. Analog set point values are connected to channel 6, and are temporarily stored in FW 22. FB 251 then reads the register and outputs it on the analog output port.

PROGRAM BLOCKS 20,21,22,23,24,25

These program blocks read the analog signal from the analog input port allocated for set point value which is channel 6. Each program block is only processes if called on PB 4. The set point value is stored in FW as listed below.

PROGRAM BLOCK 5

This program block is composed of three different PB that perform the control of the water tank system. PB51 PB52 and PB53 generate the control bit, which is sent to the final control element or output devices. Status bit from program block 3 and three digital outputs from the interface module are fed in these program blocks.

PROGRAM BLOCK 51

This program block controls water tank system 1. It receives information generated by PB3 and one digital data from the interface module.

PROGRAM BLOCK 52

This program block controls water tank system 2. It receives information generated by PB3 and one digital data from the interface module.

PROGRAM BLOCK 53

This program block controls water tank system 3. It receives information generated by PB3 and one digital data from the interface module.

PROGRAM BLOCK 9

This program block handles the control signal going to the interface module. Depending on the mode of operation, digital output is generated based on the speed of the control pulse produced in PB 46. If set point adjust is selected, the monitor mode is temporarily held ,and output Q 33.7 is maintained high so that set point value can be monitored.

PROGRAM BLOCKS 7

Converted analog signal read and stored by program PB1 is handled here. Depending which parameter is selected and the mode of operation, Program block 70s are called. Flag word that stores the data is retrieved and outputted in the lone analog output port.

PROGRAM BLOCK 70

This program block outputs the data stored temporarily to FW 10 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 71

This program block outputs the data stored temporarily to FW 12 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 72

This program block outputs the data stored temporarily to FW 14 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 73

This program block outputs the data stored temporarily to FW 16 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 74

This program block outputs the data stored temporarily to FW 18 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 75

This program block outputs the data stored temporarily to FW 20 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

PROGRAM BLOCK 8

This program block handles PB 80 81 82 83 84 85. These program blocks read the set point value on channel 6 of the analog input and store it in FW. Depending on the parameter selected, it jumps conditionally to the appropriate program block.

PROGRAM BLOCK 80

This program block calls FB 251 which outputs the data read from FW 50 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T1.

PROGRAM BLOCK 81

This program block calls FB 251 which outputs the data read from FW 52 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L21.

PROGRAM BLOCK 82

This program block calls FB 251 which outputs the data read from FW 54 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T2.

PROGRAM BLOCKS 83

This program block calls FB 251 which output the data read from FW 56 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L22.

PROGRAM BLOCK 84

This program block calls FB 251 which outputs the data read from FW 58 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T3.

PROGRAM BLOCK 85

This program block calls FB 251 which outputs the data read from FW 60 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L23.

CHAPTER SIX

FUTURE DEVELOPMENT

The PLC Controlled Cascaded Water Tank System Project has several possibilities for future development. These are:

1. To make the system more flexible wherein it will run with just one or two system connected to the PLC. This will enable the student to learn the operation of PLC more easily.

2. To incorporate graphic display and control with the use of a computer. At the moment, the system is being run and controlled by Siemens S5-95U PLC. The Interface Module which includes the Signal Conditioning Unit and the Display Module is designed specifically for this purpose.

3. To add more parameters to the system so that the use of the PLC will be fully maximised.

4. The hysteresis level of the control should be dealt with more closely, to minimise cyclic action and hardware wear and tear such as overheating the pump and worning out the solenoids easily.

CHAPTER SEVEN

CONCLUSION

This project "PLC Controlled Cascaded Water Tank System" is completed and operates accordingly as originally planned. It was able to bring out the best features of the PLC and demonstrates satisfactorily the capability and flexibility of the equipment.

Another important thing in this project is that it has fully exploited almost all the features available in the S5-95U Model of Siemens. The use of analog value processing makes it more interesting and more distinct compared to the conventional relay logic control.

The design of Interface and Display Module is also successful and allows the user to monitor the different parameters in the system. The interface is partially controlled by the PLC because of the limited analog output available on the PLC.

APPENDIX 1

REFERENCES:

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Webb, John W; Reis, Ronald A, *Programmable Logic Controller: Principle and applications*, Englewoods Cliff, NJ: Prentice Hall Education, Career and Technology, 1995.

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National Semiconductor Corporation, *Linear Databook*, Santa Clara, California, 1980.

PROGRAM: Cascaded Water Tank System

ORGANISATIONAL BLOCK 1

```
:JU PB46
:JU PB1
:JU PB3
:JU PB4
:JU PB5
:JU PB6
:JU PB9
```

PROGRAM BLOCK 46

COMMENT:

This program block generates a control pulse sent to the interface module used for monitoring the process variable and the set point value.

```
DB5     : holds the variable time parameter to set
          the speed of  the  clock pulse.  Here it
          was set to 0.3 millisecond.
I0.7    : Initiates the operation of the control
          pulse generator.
F46.1   : This flag is set when timer 1 preset time
          has lapsed. It activates timer 2 and
          deactivates timer 4.
F46.2   : This flag is set when timer 2 preset time
          has lapsed. It activates timer 3      and
          deactivates timer 1.
F46.3   : This flag is set when timer 3 preset time
          has lapsed. It activates timer 4 and
          activates timer 2.
F46.4   : This flag is set when timer 4 preset time
          has lapsed. It activates timer 1 and
          deactivates timer 3
T1      : Timer 1
T2      : Timer 2
T3      : Timer 3
T4      : Timer 4
```

Segment 1

```
0000      :C   DB5
```

Segment 2

```
0001      :A    F  46.4
0002      :O    I  0.7
```

```
0003        :AN  F  46.2
0004        :L   DW 5
0005        :SS  T  1
0006        :A   F  46.2
0007        :R   T  1
0008        :NOP 0
0009        :NOP 0
0010        :A   T  1
0011        :=   F  46.1
```

Segment 3

```
0012        :A   F  46.1
0013        :AN  F  46.3
0014        :L   DW 5
0015        :SS  T  2
0016        :A   F  46.3
0017        :R   T  2
0018        :NOP 0
0019        :NOP 0
0020        :A   T  2
0021        :=   F  46.2
0022        :
```

Segment 4

```
0023        :A   F  46.2
0024        :AN  F  46.4
0025        :L   DW 5
0026        :SS  T  3
0027        :A   F  46.4
0028        :R   T  3
0029        :NOP 0
0030        :NOP 0
0031        :A   T  3
0032        :=   F  46.3
0033        :
```

Segment 5

```
0034        :A   F  46.3
0035        :AN  F  46.1
0036        :L   DW 5
0037        :SS  T  4
0038        :A   F  46.1
0039        :R   T  4
0040        :NOP 0
0041        :NOP 0
0042        :A   T  2
0043        :=   F  46.4
0044        :BE
```

PROGRAM BLOCK 1

COMMENT:

Program block 1 reads the analog signal from the analog input port of the PLC. Channel 0 to channel 5 are the six channels used in this program block to read the six analog signals from the water tank system. It uses the FB 250, a special function block for reading analog signal. This analog signal is converted to digital data so that it could be stored and handled by the PLC. The digital information is stored in the temporary register called flag (Flag Word FW- since it is two byte long)

FW 10	:	Flag word that stores the scaled value of the analog signal from channel 0.
FW 12	:	Flag word that stores the scaled value of the analog signal from channel 1.
FW 14	:	Flag word that stores the scaled value of the analog signal from channel 2.
FW 16	:	Flag word that stores the scaled value of the analog signal from channel 3.
FW 18	:	Flag word that stores the scaled value of the analog signal from channel 4.
FW 20	:	Flag word that stores the scaled value of the analog signal from channel 5.
IW 40	:	Digital equivalent of the analog signal on channel 0 .
IW 42	:	Digital equivalent of the analog signal on channel 1 .
IW 44	:	Digital equivalent of the analog signal on channel 2 .
IW 46	:	Digital equivalent of the analog signal on channel 3 .
IW 48	:	Digital equivalent of the analog signal on channel 4 .
IW 50	:	Digital equivalent of the analog signal on channel 5 .

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 0,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 10
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    PW 40
000B        :T    IW 40
000C        :L    FW 10
```

Segment 2

```
000D        :JU   FB 250
000E  NAME  :RLG:AE
000F  BG    :     KF +8
0010  KNKT  :     KY 1,4
0011  OGR   :     KF +1000
0012  UGR   :     KF -0
0013  EINZ  :     F  50.0
0014  XA    :     FW 12
0015  FB    :     F  120.0
0016  BU    :     F  121.0
0017        :L    PW 42
0018        :T    IW 42
0019        :L    FW 12
```

Segment 3

```
001A        :JU   FB 250
001B  NAME  :RLG:AE
001C  BG    :     KF +8
001D  KNKT  :     KY 2,4
001E  OGR   :     KF +1000
001F  UGR   :     KF -0
0020  EINZ  :     F  50.0
0021  XA    :     FW 14
0022  FB    :     F  120.0
0023  BU    :     F  121.0
0024        :L    PW 44
0025        :T    IW 44
0026        :L    FW 14
```

Segment 4

```
0027        :JU   FB 250
0028  NAME  :RLG:AE
0029  BG    :     KF +8
```

```
002A  KNKT :     KY 3,4
002B  OGR  :     KF +1000
002C  UGR  :     KF -0
002D  EINZ :     F  50.0
002E  XA   :     FW 16
002F  FB   :     F  120.0
0030  BU   :     F  121.0
0031       :L    PW 46
0032       :T    IW 46
0033       :L    FW 16
```

Segment 5

```
0034       :JU   FB 250
0035  NAME :RLG:AE
0036  BG   :     KF +8
0037  KNKT :     KY 4,4
0037  OGR  :     KF +1000
0039  UGR  :     KF -0
003A  EINZ :     F  50.0
003B  XA   :     FW 18
003C  FB   :     F  120.0
003D  BU   :     F  121.0
003E       :L    PW 48
003F       :T    IW 48
0040       :L    FW 18
```

Segment 6

```
0041       :JU   FB 250
0042  NAME :RLG:AE
0043  BG   :     KF +8
0044  KNKT :     KY 5,4
0045  OGR  :     KF +1000
0046  UGR  :     KF -0
0047  EINZ :     F  50.0
0048  XA   :     FW 20
0049  FB   :     F  120.0
004A  BU   :     F  121.0
004B       :L    PW 50
004C       :T    IW 50
004D       :L    FW 20
004E       :BE
```

PROGRAM BLOCK 3

COMMENT:

Program block 3 generates the status bit that is used in controlling the water tank. The measurement of the process variable stored in a register say FW 10 is compared to the set point value stored in another register, say FW40 (assuming parameter T1 is selected). These two values are compared (eg. greater than or equal to operation) and a status bit is generated, high if it is or low if it is not.

FW 10	:	Flag word that stores the scaled value of the analog signal from channel 0.
FW 12	:	Flag word that stores the scaled value of the analog signal from channel 1.
FW 14	:	Flag word that stores the scaled value of the analog signal from channel 2.
FW 16	:	Flag word that stores the scaled value of the analog signal from channel 3.
FW 18	:	Flag word that stores the scaled value of the analog signal from channel 4.
FW 20	:	Flag word that stores the scaled value of the analog signal from channel 5.
FW 60	:	Flag word that stores set point value for parameter T1.
FW 62	:	Flag word that stores set point value for parameter L21.
FW 64	:	Flag word that stores set point value for parameter T3.
FW 66	:	Flag word that stores set point value for parameter L22.
FW 68	:	Flag word that stores set point value for parameter T3.
FW 70	:	Flag word that stores set point value for parameter L23.
F 1.0	:	Status bit for parameter T1.
F 1.1	:	Status bit for parameter L21.
F 1.2	:	Status bit for parameter T2.
F 1.3	:	Status bit for parameter L22.
F 1.4	:	Status bit for parameter T3
F 1.5	:	Status bit for parameter L23.

Segment 1

```
0000      :JU   PB 1
```

Segment 2

```
0001      :L    FW 20
0002      :L    FW 70
0003      :>=   F
0004      :=    F  1.5
```

Segment 3

```
0005      :L    FW 18
0006      :L    FW 68
0007      :>=   F
0008      :=    F  1.4
```

Segment 4

```
0009      :L    FW 16
000A      :L    FW 66
000B      :>=   F
000C      :=    F  1.3
```

Segment 5

```
000D      :L    FW 14
000E      :L    FW 64
000F      :>=   F
0010      :=    F  1.2
```

Segment 6

```
0011      :L    FW 12
0012      :L    FW 62
0013      :>=   F
0014      :=    F  1.1
```

Segment 7

```
0015      :L    FW 10
0016      :L    FW 60
0017      :>=   F
0018      :=    F  1.0
0019      :BE
```

PROGRAM BLOCK 4

COMMENT:

This program block allows the user to view the set point while it is being adjusted. It first determine which parameter is selected, and then jumps to PB 88 that does the reading of the analog input port and then outputs it to the output port.

Another part of this program block is the storing of the set value to a selected register. It requires the "Enter" signal to actually store the data.

```
F  5.1  : This flag bit indicates that the mode
          "Set Point Adjust" is selected.
F  7.0  : Flag bit that parameter T1 is selected.
F  7.1  : Flag bit that parameter L21 is selected.
F  7.2  : Flag bit that parameter T2 is selected.
F  7.3  : Flag bit that parameter L22 is selected.
F  7.4  : Flag bit that parameter T3 is selected.
F  7.5  : Flag bit that parameter L23 is selected.
I  32.3 : Digital input for "Enter" switch.
PB 88   : Program block that reads analog input on
          channel 6 and outputs it on output port.
PB 20   : Read and store set point value for T1.
PB 21   : Read and store set point value for L21.
PB 22   : Read and store set point value for T2.
PB 23   : Read and store set point value for L22.
PB 24   : Read and store set point value for T3.
PB 25   : Read and store set point value for L23.
```

Segment 1

```
0000     :JU   PB 6
```

Segment 2

```
0001     :A    FW 5.1
0002     :A    F  7.0
0003     :JC   PB 88
0004     :A    F  5.1
0005     :A    F  7.0
0006     :A    I  32.3
0007     :JC   PB 20
```

Segment 3

```
0008     :A    FW 5.1
0009     :A    F  7.1
000A     :JC   PB 88
000B     :A    F  5.1
000C     :A    F  7.1
```

```
000D        :A    I  32.3
000E        :JC   PB 21
```

Segment 4

```
000F        :A    FW 5.1
0010        :A    F  7.2
0011        :JC   PB 88
0012        :A    F  5.1
0013        :A    F  7.2
0014        :A    I  32.3
0015        :JC   PB 22
```

Segment 5

```
0016        :A    FW 5.1
0017        :A    F  7.3
0018        :JC   PB 88
0019        :A    F  5.1
001A        :A    F  7.3
001B        :A    I  32.3
001C        :JC   PB 23
```

Segment 6

```
001D        :A    FW 5.1
001E        :A    F  7.4
001F        :JC   PB 88
0020        :A    F  5.1
0021        :A    F  7.4
0022        :A    I  32.3
0023        :JC   PB 24
```

Segment 7

```
0024        :A    FW 5.1
0025        :A    F  7.5
0026        :JC   PB 88
0027        :A    F  5.1
0028        :A    F  7.5
0029        :A    I  32.3
002A        :JC   PB 25
002B        :BE
```

PROGRAM BLOCK 6

COMMENT:

This program block toggles the mode bit depending on the position of the mode switch. It also produces the flag bit for the parameter selected . It uses a count down counter (another feature of PLC) to perform this program block. Depending on the count of the counter, it is compared to a constant and then produces a parameter bit.

```
F  5.0  : Flag bit signifying the operation is in
          monitor mode.
F  5.1  : Flag bit signifying the operation is in
          set point adjust mode.
I  32.1 : Digital input select parameter switch
I  32.3 : Digital input counter reset from interface
C  1    : Counter 1 on PLC
F  7.0  : Flag bit that parameter T1 is selected.
F  7.1  : Flag bit that parameter L21 is selected.
F  7.2  : Flag bit that parameter T2 is selected.
F  7.3  : Flag bit that parameter L22 is selected.
F  7.4  : Flag bit that parameter T3 is selected.
F  7.5  : Flag bit that parameter L23 is selected.
```

Segment 1

```
0000     :AN  I  32.0
0001     :=   F  5.0
```

Segment 2

```
0002     :A   I  32.0
0003     :=   F  5.1
```

Segment 3

```
0004     :A   I    32.1
0005     :CD  C    1
0006     :NOP 0
0007     :O   I    32.1
0008     :0   I    0.7
0009     :L   KC   008
000A     :S   C    1
000B     :NOP 0
000C     :NOP 0
000D     :NOP 0
000E     :A   C    1
000F     :=   F    7.7
```

Segment 4

```
0010        :L    C    1
0011        :L    KC   007
0012        :!=   F
0013        :=    F   7.6
```

Segment 5

```
0014        :L    C    1
0015        :L    KC   006
0016        :!=   F
0017        :=    F   7.0
```

Segment 6

```
0018        :L    C    1
0019        :L    KC   005
001A        :!=   F
001B        :=    F   7.1
```

Segment 7

```
001C        :L    C    1
001D        :L    KC   004
001E        :!=   F
001F        :=    F   7.2
```

Segment 8

```
0020        :L    C    1
0021        :L    KC   003
0022        :!=   F
0023        :=    F   7.3
```

Segment 9

```
0024        :L    C    1
0025        :L    KC   002
0026        :!=   F
0027        :=    F   7.4
```

Segment 10

```
0028        :L    C    1
0029        :L    KC   001
002A        :!=   F
002B        :=    F   7.5
002C        :BE
```

PROGRAM BLOCK 88

COMMENT:

Reading the set point value and outputting it for display is performed by this program block. Analog set point values are connected to channel 6, and are temporarily stored in FW 22. FB 251 then reads the register and outputs it on the analog output port.

```
IW  52  : Analog input word for set point value.
FW  22  : Flag word used to store the set point
          value.
```

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF+8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF+1000
0005  UGR   :     KF-0
0006  EINZ  :     F  50.0
0007  XA    :     FW 22
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 22
000B        :T    PW 52
000C        :T    IW 52
000D        :L    FW 22
000E
0010        :JU   FB 251
0011  NAME  :RLG:AA
0012  XE    :     FW 22
0013  BG    :     KF +8
0014  KNKT  :     KY 0,0
0015  OGR   :     KF +1000
0016  UGR   :     KF -0
0017  FEH   :     F  120.1
0018  BU    :     F  121.1
0019        BE
```

PROGRAM BLOCKS 20,21,22,23,24,25

COMMENT:

These program blocks read the analog signal from the analog input port allocated for set point value which is channel 6. Each program block is only processes if called on PB 4. The set point value is stored in FW as listed below.

```
FW 50  : Flag word allocated for T1 from input.
FW 52  : Flag word allocated for L21 from input.
FW 54  : Flag word allocated for T2 from input.
FW 56  : Flag word allocated for L22 from input.
FW 58  : Flag word allocated for T3 from input.
FW 60  : Flag word allocated for L23 from input.
FW 30  : Flag word where scaled set point value for
         T1 is stored.
FW 32  : Flag word where scaled set point value for
         L21 is stored.
FW 34  : Flag word where scaled set point value for
         T2 is stored.
FW 36  : Flag word where scaled set point value for
         L22 is stored.
FW 38  : Flag word where scaled set point value for
         T3 is stored.
FW 40  : Flag word where scaled set point value for
         L23 is stored.
```

PROGRAM BLOCK 20

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 50
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 50
000B        :T    FW 30
000C        :BE
```

PROGRAM BLOCK 21

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 52
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 52
000B        :T    FW 32
000C        :BE
```

PROGRAM BLOCK 22

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 54
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 54
000B        :T    FW 34
000C        :BE
```

PROGRAM BLOCK 23

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 56
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 56
000B        :T    FW 36
000C        :BE
```

PROGRAM BLOCK 24

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 58
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 58
000B        :T    FW 38
000C        :BE
```

PROGRAM BLOCK 25

Segment 1

```
0000        :JU   FB 250
0001  NAME  :RLG:AE
0002  BG    :     KF +8
0003  KNKT  :     KY 6,4
0004  OGR   :     KF +1000
0005  UGR   :     KF -0
0006  EINZ  :     F  50.0
0007  XA    :     FW 60
0008  FB    :     F  120.0
0009  BU    :     F  121.0
000A        :L    FW 60
000B        :T    FW 40
000C        :BE
```

PROGRAM BLOCK 5

COMMENT:

This program block is composed of three different PB that perform the control of the water tank system. PB51 PB52 and PB53 generate the control bit, which is sent to the final control element or output devices. Status bit from program block 3 and three digital outputs from the interface module are fed in these program blocks.

```
PB 51  : Control program for water tank system 1.
PB 52  : Control program for water tank system 2.
PB 53  : Control program for water tank system 3.
```

Segment 1

```
0000       :JU  PB   51
0001       :JU  PB   52
0002       :JU  PB   53
```

PROGRAM BLOCK 51

This program block controls water tank system 1. It receives information generated by PB3 and one digital data from the interface module.

```
I 33.0 : Digital input on status of L11.
Q 32.0 : Digital output for Cold Water valve WTS 1
Q 32.2 : Digital output for Hot water valve WTS 1
Q 32.3 : Digital output for Feed pump WTS 1
Q 32.4 : Digital output for Recycling pump WTS 1
Q 32.5 : Digital output for Drain/Process pump WTS 1
F  1.0 : Status bit for parameter T1.
F  1.1 : Status bit for parameter L21.
```

Segment 1

```
0000       :AN  F  1.0
0001       :AN  F  1.1
0002       :=   Q  32.0
```

Segment 2

```
0003       :AN  F  1.0
0004       :O
0005       :AN  F  1.1
0006       :=   Q  32.1
```

Segment 3

```
0007     :A    F  1.0
0008     :A    I  33.0
0009     :AN   F  1.1
000A     :=    Q  32.2
```

Segment 4

```
000E     :A    F  1.0
000F     :AN   I  33.0
0010     :=    Q  32.3
```

Segment 5

```
0011     :AN   F  1.0
0012     :A    F  1.1
0013     :=    Q  32.4
0014     :BE
```

PROGRAM BLOCK 52

This program block controls water tank system 2. It receives information generated by PB3 and one digital data from the interface module.

```
I 33.1 : Digital input on status of L12.
Q 32.5 : Digital output for Cold Water Valve WTS 2
Q 32.6 : Digital output for Hot water valve WTS 2
Q 32.7 : Digital output for Feed pump WTS 2
Q 33.0 : Digital output for Recycling pump WTS 2
Q 33.1 : Digital output for Drain/Process pump WTS 2
F  1.2 : Status bit for parameter T2.
F  1.3 : Status bit for parameter L22.
```

Segment 1

```
0000     :AN   F  1.2
0001     :AN   F  1.3
0002     :=    Q  32.5
```

Segment 2

```
0003     :AN   F  1.0
0004     :O
0005     :AN   F  1.1
0006     :=    Q    32.6
```

Segment 3

```
0007     :A    F   1.2
0008     :A    I   33.1
0009     :AN   F   1.3
000A     :=    Q   32.7
```

Segment 4

```
000E     :A    F   1.2
000F     :AN   I   33.1
0010     :=    Q   33.0
```

Segment 5

```
0011     :AN   F   1.2
0012     :A    F   1.3
0013     :=    Q   33.1
0014     :BE
```

PROGRAM BLOCK 53

This program block controls water tank system 3. It receives information generated by PB3 and one digital data from the interface module.

```
I 33.2 : Digital input on status of L13.
Q 33.2 : Digital output for Cold Water Valve WTS 3
Q 33.3 : Digital output for Hot water valve WTS 3
Q 33.4 : Digital output for Feed pump WTS 3
Q 33.5 : Digital output for Recycling pump WTS 3
Q  0.6 : Digital output for Drain pump WTS 3
F  1.4 : Status bit for parameter T3.
F  1.5 : Status bit for parameter L23.
```

Segment 1

```
0000     :AN   F   1.4
0001     :AN   F   1.5
0002     :=    Q   33.2
```

Segment 2

```
0003     :AN   F   1.4
0004     :O
0005     :AN   F   1.5
0006     :=    Q   33.3
```

Segment 3

```
0007    :A   F  1.4
0008    :A   I  33.2
0009    :AN  F  1.5
000A    :=   Q  33.4
```

Segment 4

```
000E    :A   F  1.4
000F    :AN  I  33.2
0010    :=   Q  33.5
```

Segment 5

```
0011    :AN  F  1.4
0012    :A   F  1.5
0013    :=   O  0.1
0014    :BE
```

PROGRAM BLOCK 9

COMMENT:

This program block handles the control signal going to the interface module. Depending on the mode of operation, digital output is generated based on the speed of the control pulse produced in PB 46. If set point adjust is selected, the monitor mode is temporarily held, and output Q 33.7 is maintained high so that set point value can be monitored.

```
F  5.0 : Flag bit signifying the operation is in
         monitor mode.
F 46.1 : Flag bit that serves as control pulse
         needed by the interface module used to
         display measured variable.
F 46.3 : Flag bit that serves as control pulse
         needed by the interface module used to
         display set point value.
Q 33.6 : Digital output used as control pulse for
         monitor operation.
Q 33.7 : Digital output used as control pulse for
         set point adjust operation.
```

Segment 1

```
0000     :JU   PB 46
0001     :
0002     :A    F  46.1
0003     :AN   F  5.1
0004     :=    Q  33.6
0005     :
0006     :A    F  5.0
0007     :A    F  46.1
0008     :JU   PB 7
0009     :JU   PB 46
000A     :
000B     :A    F  46.3
000C     :O    F  5.1
000D     :=    Q  33.7
000E     :
000F     :AN   F  5.1
0010     :A    F  46.1
0011     :JU   PB 8
0012     :
0013     :A    F  5.1
0014     :JC   PB 4
0015     :BE
```

PROGRAM BLOCKS 7

COMMENT:

Converted analog signal read and stored by program PB1 is handled here. Depending which parameter is selected and the mode of operation, Program block 70s are called. Flag word that stores the data is retrieved and outputted in the lone analog output port.

```
F  5.0 : Flag bit signifying the operation is in
         monitor mode.
F  7.0 : Flag bit that parameter T1 is selected.
F  7.1 : Flag bit that parameter L21 is selected.
F  7.2 : Flag bit that parameter T2 is selected.
F  7.3 : Flag bit that parameter L22 is selected.
F  7.4 : Flag bit that parameter T3 is selected.
F  7.5 : Flag bit that parameter L23 is selected.
```

Segment 1

```
0000     :JU   PB 6
```

Segment 2

```
0001     :A    F  5.0
0002     :A    F  7.0
0003     :JC   PB 70
```

Segment 3

```
0004     :A    F  5.0
0005     :A    F  7.1
0006     :JC   PB 71
```

Segment 4

```
0007     :A    F  5.0
0008     :A    F  7.2
0009     :JC   PB 72
```

Segment 5

```
000A     :A    F  5.0
000B     :A    F  7.3
000C     :JC   PB 73
```

Segment 6

```
000D     :A    F  5.0
000E     :A    F  7.4
000F     :JC   PB 74
```

Segment 7

```
0010     :A    F  5.0
0011     :A    F  7.5
0012     :JC   PB 75
0013     :BE
```

PROGRAM BLOCK 70

COMMENT:

This program block outputs the data stored temporarily to FW 10 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 10
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F  120.1
0008  BU    :    F  121.1
0009        :L   FW 10
000A        :T   FW 110
000B        :BE
```

PROGRAM BLOCK 71

COMMENT:

This program block outputs the data stored temporarily to FW 12 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 12
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F
0008  BU    :    F  121.1
0009        :L   FW 12
000A        :T   FW 112
000B        :BE
```

PROGRAM BLOCK 72

COMMENT:

This program block outputs the data stored temporarily to FW 14 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 14
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -0
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :L    FW 14
000A        :T    FW 114
000B        :BE
```

PROGRAM BLOCK 73

COMMENT:

This program block outputs the data stored temporarily to FW 16 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 16
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -0
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :L    FW 16
000A        :T    FW 116
000B        :BE
```

PROGRAM BLOCK 74

COMMENT:

This program block outputs the data stored temporarily to FW 18 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 18
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F  120.1
0008  BU    :    F  121.1
0009        :L   FW 18
000A        :T   FW 118
000B        :BE
```

PROGRAM BLOCK 75

COMMENT:

This program block outputs the data stored temporarily to FW 20 during PB 1. When this program block is called depending on the parameter and mode selected, it performs FB 251 which outputs the converted analog data to the analog output port.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 20
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F  120.1
0008  BU    :    F  121.1
0009        :L   FW 20
000A        :T   FW 120
000B        :BE
```

PROGRAM BLOCK 8

COMMENT:

This program block handles PB 80 81 82 83 84 85. These program blocks read the set point value on channel 6 of the analog input and store it in FW. Depending on the parameter selected, it jumps conditionally to the appropriate program block.

```
F  5.0 : Flag bit signifying the operation is in
         monitor mode.
F  5.1:  Flag bit signifying the operation is in
         set point adjust mode.
F  7.0 : Flag bit that parameter T1 is selected.
F  7.1 : Flag bit that parameter L21 is selected.
F  7.2 : Flag bit that parameter T2 is selected.
F  7.3 : Flag bit that parameter L22 is selected.
F  7.4 : Flag bit that parameter T3 is selected.
F  7.5 : Flag bit that parameter L23 is selected.
```

Segment 1

```
0000      :A    (
0001      :O    F  5.0
0002      :O    F  5.1
0003      :)
0004      :A    F  7.0
0005      :JC   PB 80
```

Segment 2

```
0006      :A    (
0007      :O    F  5.0
0008      :O    F  5.1
0009      :)
000A      :A    F  7.1
000B      :JC   PB 81
```

Segment 3

```
000C      :A    (
000D      :O    F  5.0
000E      :O    F  5.1
000F      :)
0010      :A    F  7.2
0011      :JC   PB 82
```

Segment 4

```
0012    :A    (
0013    :O    F  5.0
0014    :O    F  5.1
0015    :)
0016    :A    F  7.3
0017    :JC   PB 83
```

Segment 5

```
0018    :A    (
0019    :O    F  5.0
001A    :O    F  5.1
001B    :)
001C    :A    F  7.4
001D    :JC   PB 84
```

Segment 6

```
001E    :A    (
001F    :O    F  5.0
0020    :O    F  5.1
0021    :)
0022    :A    F  7.5
0023    :JC   PB 85
0024    :BE
```

PROGRAM BLOCK 80

COMMENT:

This program block calls FB 251 which outputs the data read from FW 50 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T1.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 50
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F  120.1
0008  BU    :    F  121.1
0009        :BE
```

PROGRAM BLOCK 81

COMMENT:

This program block calls FB 251 which outputs the data read from FW 52 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L21.

Segment 1

```
0000        :JU  FB 251
0001  NAME  :RLG:AA
0002  XE    :    FW 52
0003  BG    :    KF +8
0004  KNKT  :    KY 0,0
0005  OGR   :    KF +1000
0006  UGR   :    KF -0
0007  FEH   :    F  120.1
0008  BU    :    F  121.1
0009        :BE
```

PROGRAM BLOCK 82

COMMENT:

This program block calls FB 251 which outputs the data read from FW 54 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T2.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 54
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -100
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :BE
```

PROGRAM BLOCKS 83

COMMENT:

This program block calls FB 251 which output the data read from FW 56 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L22.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 56
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -0
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :BE
```

PROGRAM BLOCK 84

COMMENT:

This program block calls FB 251 which outputs the data read from FW 58 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is T3.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 58
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -0
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :BE
```

PROGRAM BLOCK 85

COMMENT:

This program block calls FB 251 which outputs the data read from FW 60 to analog signal to the output port. This program block is executed either by monitor mode or set point adjust mode and the parameter selected is L23.

Segment 1

```
0000        :JU   FB 251
0001  NAME  :RLG:AA
0002  XE    :     FW 60
0003  BG    :     KF +8
0004  KNKT  :     KY 0,0
0005  OGR   :     KF +1000
0006  UGR   :     KF -0
0007  FEH   :     F  120.1
0008  BU    :     F  121.1
0009        :BE
```

QUICK REFERENCE

FLAG BITS

```
F  1.0 : Status bit for parameter T1.
F  1.1 : Status bit for parameter L21.
F  1.2 : Status bit for parameter T2.
F  1.3 : Status bit for parameter L22.
F  1.4 : Status bit for parameter T3
F  1.5 : Status bit for parameter L23.
F  1.0 : Status bit for parameter T1.
F  1.1 : Status bit for parameter L21.
F  1.4 : Status bit for parameter T3.
F  1.5 : Status bit for parameter L23.
F  5.0 : Flag bit signifying the operation is in
         monitor mode.
F  5.1  : Flag bit signifying the operation is in
          set point adjust mode.
F  7.0  : Flag bit that parameter T1 is selected.
F  7.1  : Flag bit that parameter L21 is selected.
F  7.2  : Flag bit that parameter T2 is selected.
F  7.3  : Flag bit that parameter L22 is selected.
F  7.4  : Flag bit that parameter T3 is selected.
F  7.5  : Flag bit that parameter L23 is selected.

F 46.1 : This flag is set when timer 1 preset time
         has lapsed. It activates timer 2 and
         deactivates timer 4.
F 46.1 : Flag bit that serves as control pulse
         needed by the interface module used to
          display measured variable.
F 46.2 : This flag is set when timer 2 preset time
         has lapsed. It activates timer 3
         and deactivates timer 1.
F 46.3 : This flag is set when timer 3 preset time
         has lapsed. It activates timer 4 and
         eactivates timer 2.
F 46.3 : Flag bit that serves as control pulse
         needed by the interface module used to
          display set point value.
F 46.4 : This flag is set when timer 4 preset time
         has lapsed. It activates timer 1 and
         deactivates timer 3
```

FLAG WORDS

FW 10 : Flag word that stores the scaled value of the analog signal from channel 0.
FW 12 : Flag word that stores the scaled value of the analog signal from channel 1.
FW 14 : Flag word that stores the scaled value of the analog signal from channel 2.
FW 16 : Flag word that stores the scaled value of the analog signal from channel 3.
FW 18 : Flag word that stores the scaled value of the analog signal from channel 4.
FW 20 : Flag word that stores the scaled value of the analog signal from channel 5.
FW 22 : Flag word used to store the set point value.
FW 30 : Flag word where scaled set point value for T1 is stored.
FW 32 : Flag word where scaled set point value for L21 is stored.
FW 34 : Flag word where scaled set point value for T2 is stored.
FW 36 : Flag word where scaled set point value for L22 is stored.
FW 38 : Flag word where scaled set point value for T3 is stored.
FW 40 : Flag word where scaled set point value for L23 is stored.
FW 50 : Flag word allocated for T1 from input.
FW 52 : Flag word allocated for L21 from input.
FW 54 : Flag word allocated for T2 from input.
FW 56 : Flag word allocated for L22 from input.
FW 58 : Flag word allocated for T3 from input.
FW 60 : Flag word allocated for L23 from input.

FW 62 : Flag word that stores set point value for parameter L21.
FW 64 : Flag word that stores set point value for parameter T3.
FW 66 : Flag word that stores set point value for parameter L22.
FW 68 : Flag word that stores set point value for parameter T3.
FW 70 : Flag word that stores set point value for parameter L23.

INPUT BITS/ WORDS

```
I   32.2 : Initiates the operation of the control
           pulse generator.
I   32.1 : Digital input "Mode Select" switch
I   32.1 : Digital input "Select Parameter" switch
I   32.2 : Digital input for "Enter" switch.

I 33.0 : Digital input on status of L11.
I 33.1 : Digital input on status of L12.
I 33.2 : Digital input on status of L13.

IW 40  : Digital equivalent of the analog signal on
         channel 0 .
IW 42  : Digital equivalent of the analog signal on
         channel 1 .
IW 44  : Digital equivalent of the analog signal on
         channel 2 .
IW 46  : Digital equivalent of the analog signal on
         channel 3 .
IW 48  : Digital equivalent of the analog signal on
         channel 4 .
IW 50  : Digital equivalent of the analog signal on
         channel 5 .
IW 52  :  Analog input word for set point value.
```

OUTPUT BITS

```
Q 32.0 : Digital output for Cold Water valve WTS 1
Q 32.2 : Digital output for Hot water valve WTS 1
Q 32.3 : Digital output for Feed pump WTS 1
Q 32.4 : Digital output for Recycling pump WTS 1
Q 32.5 : Digital output for Drain/Process pump WTS 1
Q 32.5 : Digital output for Cold Water Valve WTS 2
Q 32.6 : Digital output for Hot water valve WTS 2
Q 32.7 : Digital output for Feed pump WTS 2
Q 33.0 : Digital output for Recycling pump WTS 2
Q 33.1 : Digital output for Drain/Process pump WTS 2
Q 33.2 : Digital output for Cold Water Valve WTS 3
Q 33.3 : Digital output for Hot water valve WTS 3
Q 33.4 : Digital output for Feed pump WTS 3
Q 33.5 : Digital output for Recycling pump WTS 3
Q  0.6 : Digital output for Drain pump WTS 3
Q 33.6 : Digital output used as control pulse for
         monitor operation.
Q 33.7 : Digital output used as control pulse for
         set point adjust operation.
```

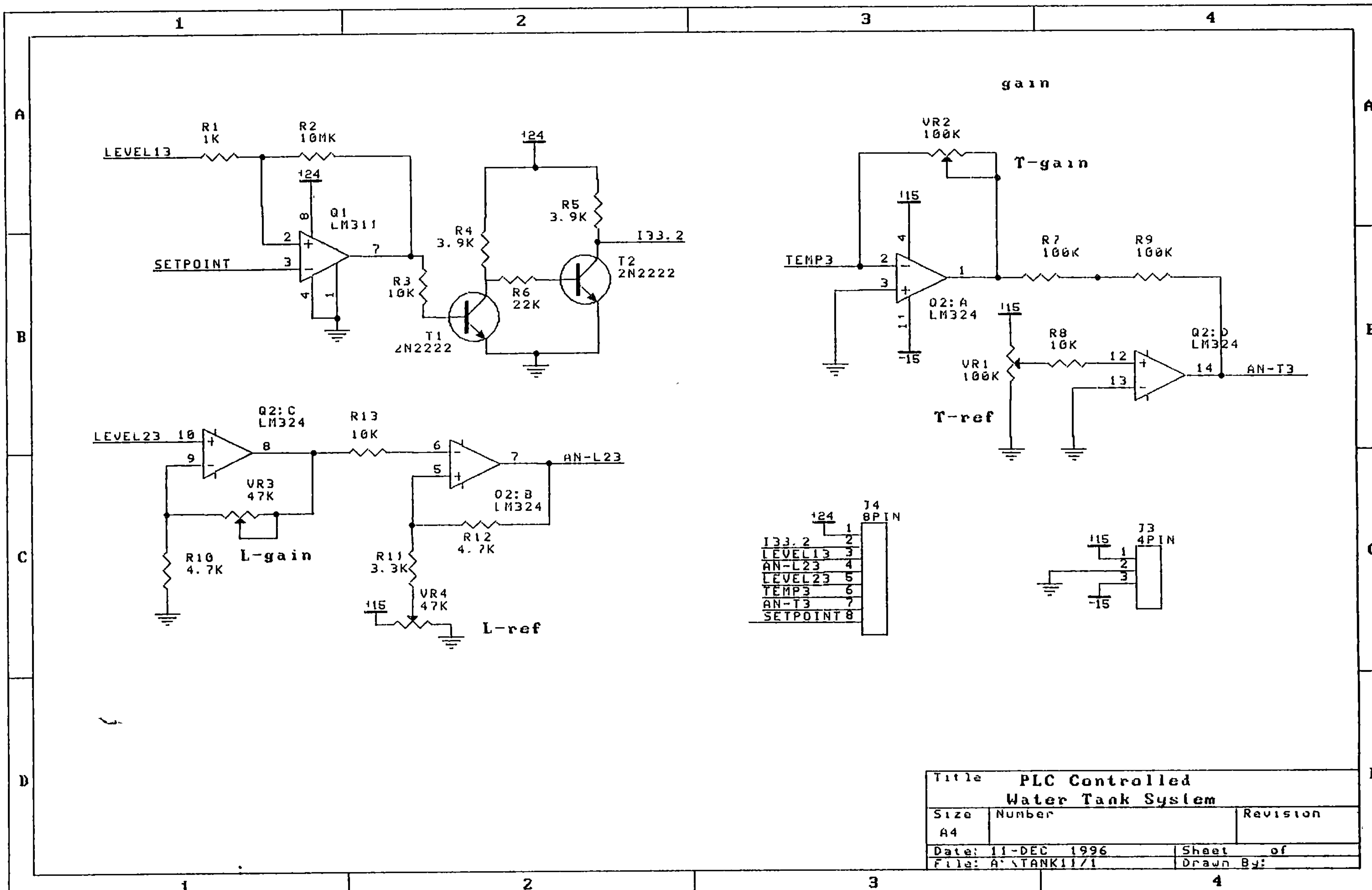
OTHERS

```
DB5    : holds the variable time parameter to set
         the speed of  the  clock pulse.  Here it
         was set to 0.3 milisecond.
T1     : Timer 1
T2     : Timer 2
T3     : Timer 3
T4     : Timer 4
C  1   : Counter 1
PB 88  : Program block that reads analog input on
          channel 6 and outputs it on output port.
PB 20  : Read and store set point value for T1.
PB 21  : Read and store set point value for L21.
PB 22  : Read and store set point value for T2.
PB 23  : Read and store set point value for L22.
PB 24  : Read and store set point value for T3.
PB 25  : Read and store set point value for L23.
PB 51  : Control program for water tank system 1.
PB 52  : Control program for water tank system 2.
PB 53  : Control program for water tank system 3.
```

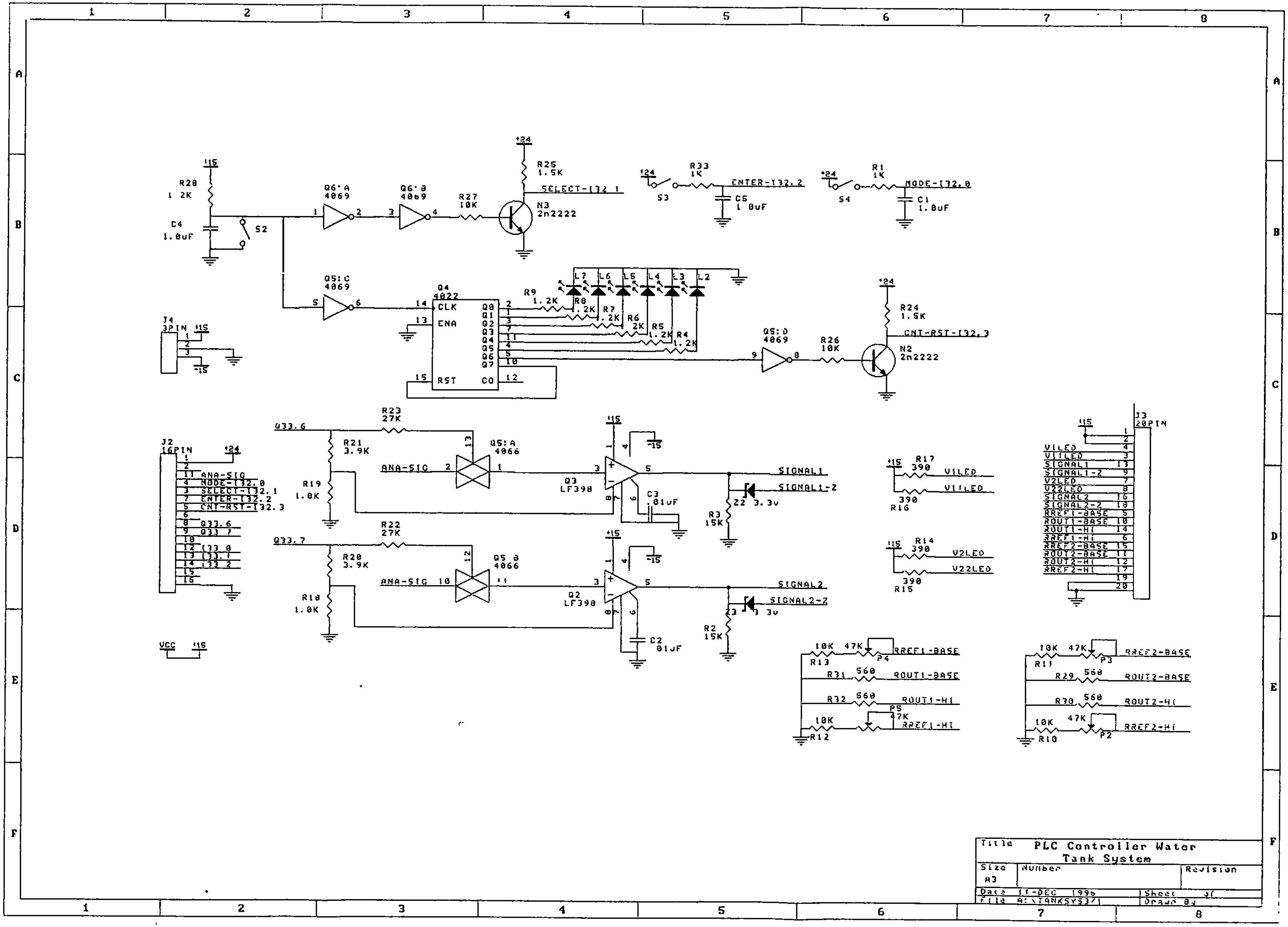
APPENDIX 3

SCHEMATIC DIAGRAMS

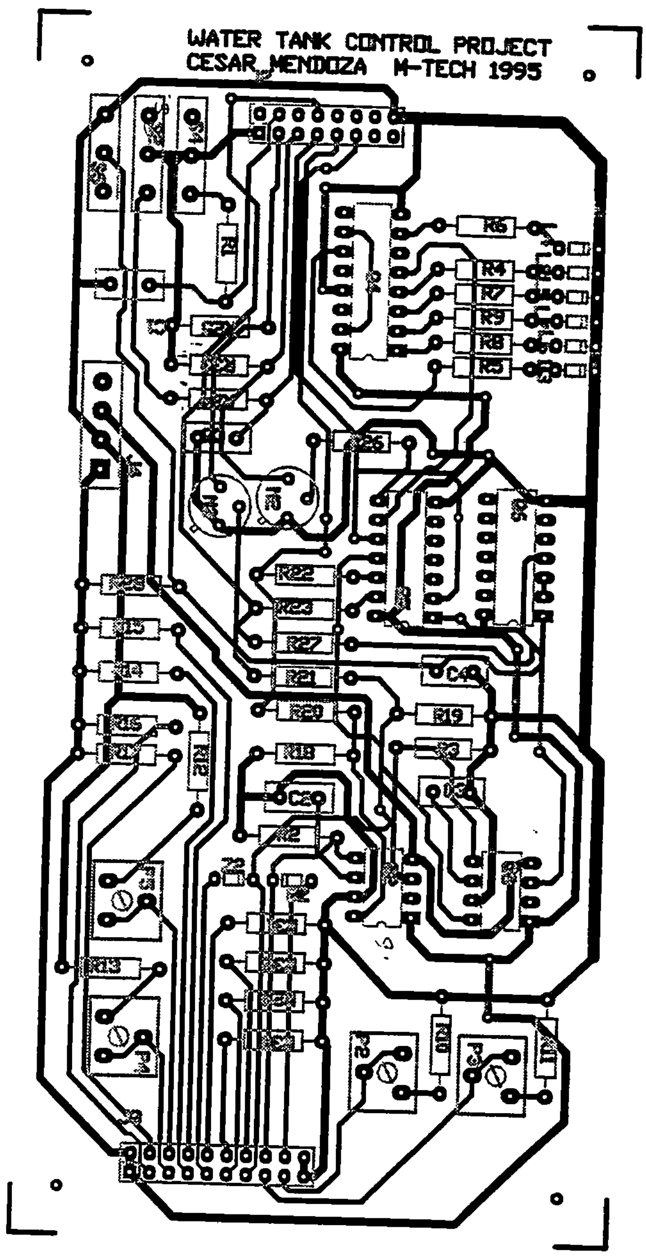
PCB Layouts



gain
LEVEL13
R1 1K
R2 10MK
+24
Q1 LM311
SETPOINT
R3 10K
R4 3.9K
R5 3.9K
R6 22K
T1 2N2222
T2 2N2222
I33.2
VR2 100K
T-gain
+15
TEMP3
R7 100K
R9 100K
Q2:A LM324
-15
R8 10K
VR1 100K
Q2:D LM324
AN-T3
T-ref
LEVEL23
Q2:C LM324
R13 10K
VR3 47K
L-gain
R10 4.7K
Q2:B LM324
AN-L23
R12 4.7K
R11 3.3K
VR4 47K
L-ref
J4 8PIN
I33.2
LEVEL13
AN-L23
LEVEL23
TEMP3
AN-T3
SETPOINT
J3 4PIN
Title PLC Controlled Water Tank System
Size A4
Number
Revision
Date: 11-DEC 1996
Sheet of
File: A:\TANK11/1
Drawn By:

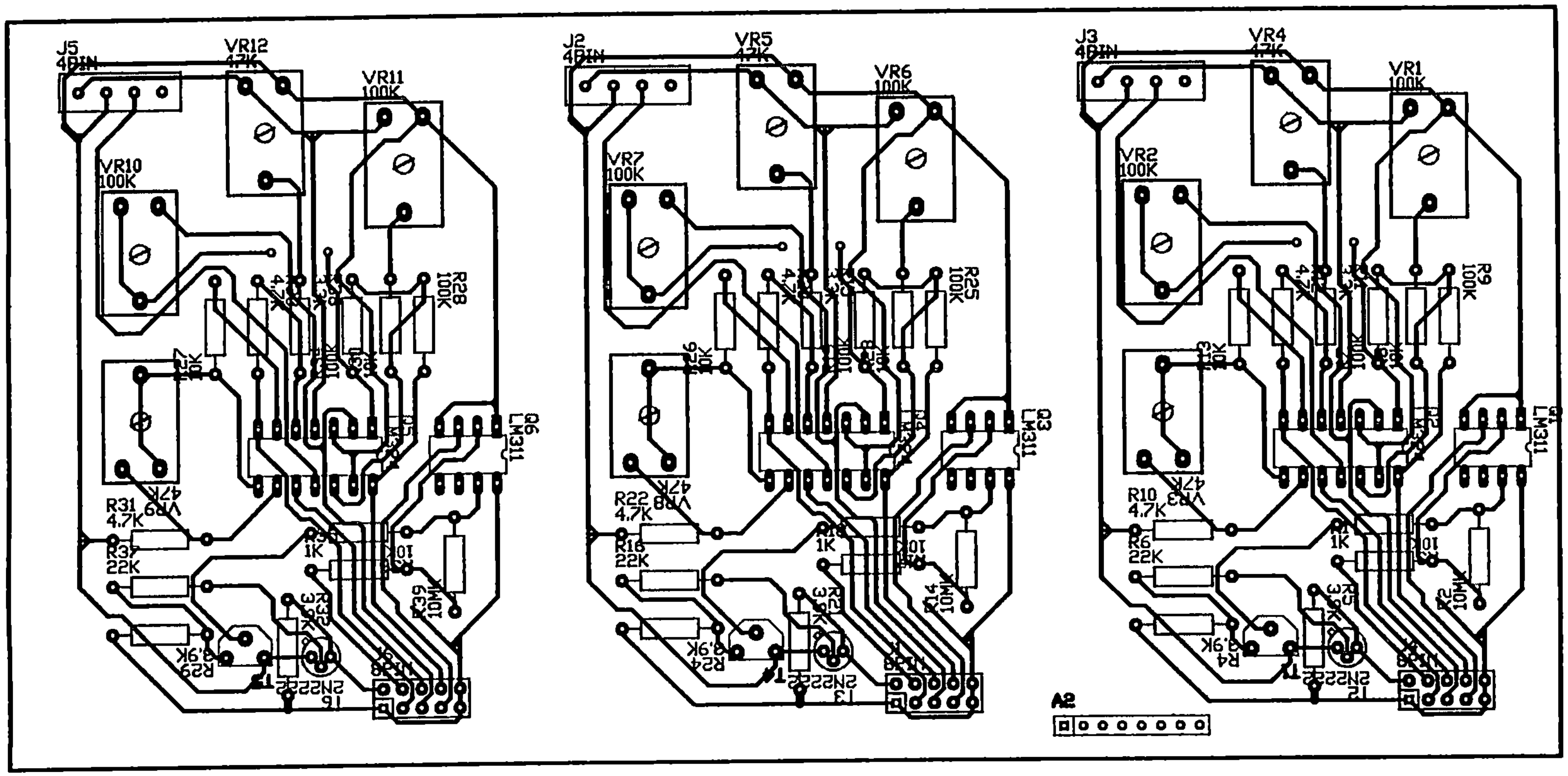


Title	PLC Controller Water Tank System	
Size A3	Number	Revision
Date 11-DEC-1996		Sheet
File A:\TANKSYS3\1		Drawn By



PCB Layout

1. **Interface Module**



PCB Layout

2. Signal Conditioning Unit